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Arsenic Removal from Drinking Water by Adsorptive Media U.S. EPA Demonstration Project at Richmond Elementary School in Susanville, CA Final Performance Evaluation Report

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Sally Gutierrez, Director
National Risk Management Research Laboratory

ABSTRACT

This report documents the activities performed and the results obtained for the arsenic removal treatment technology demonstration project at Richmond Elementary School in Susanville, CA. The objectives of the project were to evaluate: (1) the effectiveness of an Aquatic Treatment Systems, Inc. (ATS) arsenic removal system in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 µg/L, (2) the reliability of the treatment system, (3) the required system operation and maintenance (O&M) and operator skills, and (4) the capital and O&M cost of the technology. The project also characterizes water in the distribution system and residuals produced by the treatment process.

The ATS system consisted of three Well-X-TROL pressure tanks; one 25-µm sediment filter; two 10-in diameter, 54-in tall oxidation columns; three 10-in diameter, 54-in tall adsorption columns; and one pressure tank/booster pump assembly before entering the distribution system. Constructed of sealed polyglass, the columns were loaded with 1.5 ft^3 each of either A/P Complex 2002 oxidizing media (consisting of activated alumina and sodium metaperiodate) or A/I Complex 2000 adsorptive media (consisting of activated alumina and a proprietary iron complex) for series operations. Based on the design flowrate of 12 gal/min (gpm), the empty bed contact time (EBCT) in each column was 0.9 min (or 2.8 min for three adsorption columns in series) and the hydraulic loading rate to each column was 22 gpm/ft^2. Because the actual flowrate through the system was slightly lower at 9.3 gpm (on average), the actual EBCT was slightly longer at 1.2 min and the actual hydraulic loading rate was slightly lower at 17.2 gpm/ft^2.

Between September 7, 2005, and June 13, 2007, the treatment system operated for an average of 1.1 hr/day for a total of 442 hr, treating approximately 303,000 gal of water containing 25.1 to 35.4 µg/L of arsenic. Arsenic in raw water existed as both soluble As(V) and soluble As(III), with As(III) concentrations remaining below 47% of the soluble arsenic throughout most of the study period (except for the first two months). Oxidation of As(III) was achieved through reactions with sodium metaperiodate (IO_4^-) within the oxidation columns, producing As(V) and I^- as end products. The oxidation columns remained effective for As(III) oxidation throughout the study period, reducing As(III) concentrations to less than 2.7, 1.2, and 1.0 µg/L following the first and second oxidation columns and the third adsorption column, respectively. As much as 264 µg/L of IO_4^- (as I) had leached from the oxidation and adsorption columns, but the leaching followed an apparent decreasing trend.

The oxidizing media showed a significant adsorptive capacity for arsenic (i.e., 0.18 to 0.20 µg of As/mg of dry media), effectively reducing arsenic concentrations to <10 µg/L after processing 51,600 gal of water through the lead oxidation column (or 4,600 bed volumes [BV; 1 BV = 1.5 ft^3 = 11.22 gal]). Complete arsenic breakthrough from the lead and lag oxidation columns occurred after processing 79,700 and 193,000 gal of water, respectively, which correspond to 7,100 BV (1 BV = 11.22 gal) through the lead column and 8,600 BV (1 BV = 22.44 gal) through the lead and lag columns.

Arsenic breakthrough of 10 µg/L following the lead and first lag adsorption columns occurred after processing approximately 184,000 and 221,000 gal of water. Complete arsenic breakthrough for the lead adsorption column took place after processing approximately 227,800 gal of water. The arsenic loading on the lead adsorption column was 0.23 µg of As/mg of dry media, which was very close to that on the oxidation columns as mentioned above. These adsorptive capacities were very close to those observed at another EPA arsenic demonstration site in Wales, ME, where a similar ATS system was used for arsenic removal.

The lead and the first lag adsorption columns with spent adsorptive media were replaced after approximately 18 months of operation. Before changeout, the total arsenic concentration in the system

effluent was 8.4 µg/L, less than the 10 µg/L MCL. The spent media in both vessels passed the Toxicity Characteristic Leaching Procedure (TCLP) test and could be disposed off at a sanitary landfill. However, the vendor recycled the spent media into another product, thus saving the disposal cost.

Comparison of distribution system water sampling results before and after system startup showed a significant decrease in arsenic concentration at the three sampling locations during the 12 monthly sampling events. Arsenic concentrations were reduced from an average baseline level of 30.6 to 1.5 µg/L, which, although low, were still higher than the concentrations (≤0.2 µg/L) measured at the distribution entry point. Therefore, some dissolution and/or resuspension of arsenic might have occurred in the distribution system. Lead and copper values also were low and did not appear to have been affected by the treatment system.

The capital investment cost of $16,930 included $8,640 for equipment, $3,400 for site engineering, and $4,890 for installation. Using the system's rated capacity of 12 gpm (or 17,280 gal per day [gpd]), the capital cost was $1,410/gpm (or $0.98/gpd). The annualized capital cost was $1,598/yr based upon a 7% interest rate and a 20-year return. The unit capital cost was $0.25/1,000 gal assuming the system operated continuously at 24 hr/day, 7 day/wk at 12 gpm. At the current usage rate of 180,520 gal per year, the unit capital cost increased to $8.90/1,000 gal.

The O&M cost included only incremental cost associated with the adsorption system, such as media replacement and disposal, electricity consumption, and labor. The incremental cost for electricity consumption was negligible. The cost to replace the lead and first lag adsorption columns was $2,310. Labor and travel would add approximately $1,660 to the total cost. This cost was used to estimate the O&M cost per 1,000 gal of water treated as a function of the media run length to the 10-µg/L arsenic in the system effluent.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
AWWA	American Water Works Association
bgs	below ground surface
BV	bed volume(s)
Ca	calcium
CCR	California Code of Regulations
C/F	coagulation/filtration
Cl	chlorine
Cu	copper
DPH	Department of Public Health
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
GFH	granular ferric hydroxide
gpd	gallons per day
gpm	gallons per minute
HIX	hybrid ion exchanger
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	(EPA) Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.
Mg	magnesium
Mn	manganese
mV	millivolts

N/A	not analyzed
Na	sodium
NA	not applicable
ND	not detected
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
Pb	lead
PO_4	orthophosphate
POU	point-of-use
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RO	reverse osmosis
RPD	relative percent difference
SBMHP	Spring Brook Mobile Home Park
SDWA	Safe Drinking Water Act
SiO_2	silica
SO_4	sulfate
STS	Severn Trent Services
TCCI	TCCI Laboratories
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TO	task order
TOC	total organic carbon

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Section 1.0: INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the U.S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975, under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic (As) at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule requires all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration project. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site.

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites and the water system at Richmond Elementary School in Susanville, California was one of those selected.

In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28. Aquatic Treatment System, Inc. (ATS) As/1200CS arsenic treatment system was selected for demonstration at Richmond Elementary School site in October 2004.

As of April 2009, 39 of the 40 systems were operational and the performance evaluation of 32 systems was completed.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the Round 1 and Round 2 demonstration host sites include 25 adsorptive media (AM) systems (the Oregon Institute of Technology [OIT] site has three AM systems), 13 coagulation/filtration (C/F) systems, two ion exchange (IX) systems, 17 point-of-use (POU) units (including nine under-the-sink reverse osmosis [RO] units at the Sunset Ranch Development site and eight AM units at the OIT site), and one system modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including As, Fe, and pH) at the 40 demonstration sites. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital cost is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA website at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/publications.html.

1.3 Project Objectives

The objective of the Round 1 and Round 2 arsenic demonstration program is to conduct full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking water supplies. The specific objectives are to:

- Evaluate the performance of the arsenic removal technologies for use on small systems.
- Determine the required system operation and maintenance (O&M) and operator skill levels.
- Characterize process residuals produced by the technologies.
- Determine the capital and O&M cost of the technologies.

This report summarizes the performance of the ATS system at Richmond Elementary School in Susanville, CA from September 7, 2005, through June 13, 2007. The types of data collected included system operation, water quality data (both across the treatment train and in the distribution system), residuals, and capital and O&M cost.

Table 1-1. Summary of Round 1 and Round 2 Arsenic Removal Demonstration Sites

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38[a]	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70[b]	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	AdEdge	100	36[a]	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Stevensville, MD	Queen Anne's County	AM (E33)	STS	300	19[a]	270[c]	7.3
Houghton, NY[d]	Town of Caneadea	C/F (Macrolite)	Kinetico	550	27[a]	1,806[c]	7.6
Newark, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15[a]	1,312[c]	7.6
Springfield, OH	Chateau Estates Mobile Home Park	AM (E33)	AdEdge	250[e]	25[a]	1,615[c]	7.3
Great Lakes/Interior Plains							
Brown City, MI	City of Brown City	AM (E33)	STS	640	14[a]	127[c]	7.3
Pentwater, MI	Village of Pentwater	C/F (Macrolite)	Kinetico	400	13[a]	466[c]	6.9
Sandusky, MI	City of Sandusky	C/F (Aeralater)	Siemens	340[e]	16[a]	1,387[c]	6.9
Delavan, WI	Vintage on the Ponds	C/F (Macrolite)	Kinetico	40	20[a]	1,499[c]	7.5
Greenville, WI	Town of Greenville	C/F (Macrolite)	Kinetico	375	17	7827[c]	7.3
Climax, MN	City of Climax	C/F (Macrolite)	Kinetico	140	39[a]	546[c]	7.4
Sabin, MN	City of Sabin	C/F (Macrolite)	Kinetico	250	34	1,470[c]	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	C/F (Macrolite)	Kinetico	20	25[a]	3,078[c]	7.1
Stewart, MN	City of Stewart	C/F&AM (E33)	AdEdge	250	42[a]	1,344[c]	7.7
Lidgerwood, ND	City of Lidgerwood	Process Modification	Kinetico	250	146[a]	1,325[c]	7.2
Midwest/Southwest							
Arnaudville, LA	United Water Systems	C/F (Macrolite)	Kinetico	770[e]	35[a]	2,068[c]	7.0
Alvin, TX	Oak Manor Municipal Utility District	AM (E33)	STS	150	19[a]	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33)	AdEdge	40	56[a]	<25	8.0
Wellman, TX	City of Wellman	AM (E33)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers Association	AM (E33)	STS	320	23[a]	39	7.7
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33)	AdEdge	90[b]	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O'odham Utility Authority	AM (E33)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Arizona Water Company	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8

Table 1-1. Summary of Round 1 and Round 2 Arsenic Removal Demonstration Sites (Continued)

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Far West							
Three Forks, MT	City of Three Forks	C/F (Macrolite)	Kinetico	250	64	<25	7.5
Fruitland, ID	City of Fruitland	IX (A300E)	Kinetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO[f]	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia-I)	Filtronics	750	18	69[c]	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbsia/ARM 200/ArsenX^{np}) and POU AM (ARM 200)[g]	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (Arsenex II)	Kinetico	525	17	<25	7.5
Reno, NV	South Truckee Meadows General Improvement District	AM (GFH/Kemiron)	Siemens	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37[a]	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

AM = adsorptive media; C/F = coagulation/filtration; GFH = granular ferric hydroxide; HIX = hybrid ion exchanger; IX = ion exchange; RO = reverse osmosis
ATS = Aquatic Treatment Systems; MEI = Magnesium Elektron, Inc.; STS = Severn Trent Services

(a) Arsenic existing mostly as As(III).
(b) Design flowrate reduced by 50% after system was switched from parallel to serial configuration.
(c) Iron existing mostly as Fe(II).
(d) Withdrew from program in 2007. Selected originally to replace Village of Lyman, NE site, which withdrew from program in June 2006.
(e) Faculties upgraded Springfield, OH system from 150 to 250 gpm, Sandusky, MI system from 210 to 340 gpm, and Arnaudville, LA system from 385 to 770 gpm..
(f) Including nine residential units.
(g) Including eight under-the-sink units.

Section 2.0: SUMMARY AND CONCLUSIONS

Based on the information collected during the 21 months of operation, the following conclusions were made relating to the overall objectives of the treatment technology demonstration study.

Performance of the arsenic removal technology for use on small systems:

- The A/P Complex 2002 oxidizing media was effective at oxidizing As(III) to As(V), typically lowering As(III) concentrations from an average of 12.1 to <1.0 µg/L throughout the 21-month study period. Oxidation was achieved via reactions with $NaIO_4$. The oxidizing media also showed significant adsorptive capacities for arsenic (i.e., 0.18 and 0.20 µg/mg of dry media) comparable to adsorptive media. As much as 264 µg/L of IO_4^- leached from the oxidizing and adsorptive media, but the leaching followed an apparent decreasing trend.
- The A/I Complex 2000 adsorptive media was effective at removing arsenic to below its MCL. The run length to breakthrough at 10 µg/L, however, was short, ranging from 4,930 to 5,470 bed volumes (BV; note that BV was calculated by considering the respective adsorption column and all preceding columns as one large column). Complete breakthrough from the lead column occurred at approximately 6,670 BV, resulting in a loading of 0.23 µg of As/mg of dry media.
- Aluminum was leached from the oxidation and adsorption columns, with concentrations (existing primarily in the soluble form) ranging from 13.9 to 40.9 µg/L. The concentrations detected were below its secondary drinking water standard.
- Arsenic concentrations in the distribution system were reduced from an average baseline level of 30.6 to 1.5 µg/L. Some dissolution and/or resuspension of arsenic might have occurred because the levels detected in the distribution were higher than the concentrations (≤0.2 µg/L) measured at the distribution entry point.

Required system operation and maintenance and operator skill levels:

- Very little attention was needed to operate and maintain the system. The weekly demand on the operator was typically 20 min to visually inspect the system and record operational parameters.
- Operation of the As/1200CS did not require additional skills beyond those necessary to operate the existing water supply equipment.

Process residuals produced by the technology:

- The system did not require backwash to operate. As a result, no backwash residual was produced.
- The only residual produced by the treatment system was spent media. The lead and first lag adsorption columns with spent media were replaced after approximately 18 months of system operation. The spent media passed the toxicity characteristic leaching procedure (TCLP) test and could be disposed of as a non-hazardous material; however, the vendor elected to recycle it into another product to save disposal cost.

Technology cost:

- Using the system's rated capacity of 12 gal/min (gpm) (or 17,280 gal/day [gpd]), the capital cost was $1,410/gpm (or $0.98/gpd).
- The cost to change out two adsorption columns (lead and first lag) at a time was $2,310 based on the invoice provided by the vendor.

Section 3.0: MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of the ATS treatment system began on September 7, 2005. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic to below the MCL of 10 μg/L through the collection of water samples across the treatment train. The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. Any unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	October 26, 2004
Project Planning Meeting Held	April 13, 2005
Draft Letter of Understanding Issued	April 22, 2005
Final Letter of Understanding Issued	May 13, 2005
Request for Quotation Issued to Vendor	May 25, 2005
Vendor Quotation Submitted to Battelle	June 8, 2005
Purchase Order Completed and Signed	July 5, 2005
Engineering Package Submitted to California DPH	July 29, 2005
System Installation and Shakedown Completed	August 16, 2005
Final Study Plan Issued	August 17, 2005
Permit issued by California DPH	August 24, 2005
Performance Evaluation Began	September 7, 2005

DPH = Department of Public Health

Table 3-2. Evaluation Objectives and Supporting Data Collection Activities

Evaluation Objectives	Data Collection
Performance	-Ability to consistently meet 10 μg/L MCL of arsenic in treated water
Reliability	-Unscheduled system downtime -Frequency and extent of repairs including a description of problems, materials and supplies needed, and associated labor and cost
System O&M and Operator Skill Requirements	-Pre- and post-treatment requirements -Level of automation for system operation and data collection -Staffing requirements including number of operators and laborers -Task analysis of preventative maintenance including number, frequency, and complexity -Chemical handling and inventory requirements -General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	-Quantity and characteristics of aqueous and solid residuals generated by system operation
Cost-Effectiveness	-Capital cost for equipment, engineering, and installation -O&M cost for chemical usage, electricity consumption, and labor

The O&M and operator skill requirements were assessed through quantitative data and qualitative considerations, including the need for pre- and/or post-treatment, level of system automation, extent of preventative maintenance activities, frequency of chemical and/or media handling and inventory, and general knowledge needed for relevant chemical processes and related health and safety practices. The staffing requirements for the system operation were recorded on an Operator Labor Hour Log Sheet.

The cost of the system was evaluated based on the capital cost per gal/min (or gpm) (or gal/day [gpd]) of design capacity and the O&M cost per 1,000 gal of water treated. This task required tracking the capital cost for equipment, engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical supply, electricity usage, and labor.

3.2 System O&M and Cost Data Collection

The plant operator performed daily, biweekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a regular basis, the plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a System Operation Log Sheet and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator would contact the Battelle Study Lead, who determined if ATS should be contacted for troubleshooting. The plant operator recorded all relevant information, including problems encountered, course of actions taken, materials and supplies used, and associated cost and labor incurred, on the Repair and Maintenance Log Sheet. On a biweekly basis, the plant operator measured several water quality parameters onsite, including temperature, pH, dissolved oxygen (DO), and oxidation-reduction potential (ORP), and recorded the data on an Onsite Water Quality Parameters Log Sheet.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for media replacement, electricity consumption, and labor. Labor for various activities, such as routine system O&M, troubleshooting and repairs, and demonstration-related work, were tracked using an Operator Labor Hour Log Sheet. The routine system O&M included activities such as completing field logs, ordering supplies, performing system inspections, and others as recommended by the vendor. The labor for demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected from the wellhead, across the treatment plant, and from the distribution system. Table 3-3 provides the sampling schedules and analytes measured during each sampling event. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2004). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial visit to Richmond Elementary School, one set of source water samples was collected and speciated using an arsenic speciation kit (see Section 3.4.1). The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for the source water sample are listed in Table 3-3.

3.3.2 Treatment Plant Water. During the system performance evaluation study, treatment plant water samples were collected by the plant operator every other week at three to six locations across the treatment train at the wellhead (IN), after oxidation columns (OA and OB), and after adsorption columns (TA, TB, and TC). Sampling, in general, was alternating between events with and without speciation

Table 3-3. Sample Collection Schedule and Analyses

Sample Type	Sample Location(s)[a]	No. of Samples	Sampling Frequency	Analytes	Date(s) Samples Collected
Source Water	At Wellhead (IN)	1	Once (during initial site visit)	Onsite: pH, temperature, DO, and ORP Off-site: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), U (total and soluble), V (total and soluble), Na, Ca, Mg, Cl, F, NH_3, NO_3, NO_2, SO_4, SiO_2, PO_4, alkalinity, turbidity, TDS and TOC	10/26/04
Treatment Plant Water	At Wellhead (IN), After Oxidation Columns (OA and OB), After Adsorption Columns (TA, TB, and TC)	3–6	Once every four weeks[b] (With Speciation)	Onsite[c]: pH, temperature, DO, and ORP Off-site: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), and SiO_2	09/19/05, 11/02/05, 11/29/05, 01/05/06, 02/02/06, 03/02/06, 03/29/06, 04/27/06, 06/01/06, 06/21/06, 07/20/06, 08/29/06, 09/13/06, 10/11/06, 11/15/06, 01/10/07, 01/31/07, 03/07/07, 03/28/07, 04/19/07, 05/16/07, 06/13/07
		4–6	Once every four weeks[b] (Without Speciation)	Onsite[c]: pH, temperature, DO, and ORP Off-site: As (total), Fe (total), Mn (total), Al (total), Ca, Mg, F, I, NO_3, S^{2-}, SO_4, SiO_2, P (total), alkalinity, and/or turbidity	10/17/05, 11/21/05, 12/14/05, 01/17/06, 02/16/06, 03/15/06, 04/11/06, 05/08/06, 06/07/06, 07/06/06, 08/01/06, 09/27/06, 10/26/06, 11/29/06, 12/13/06, 12/19/06, 01/18/07, 02/15/07, 03/15/07
Distribution Water	Three LCR Locations	3	Monthly[d]	Total As, Fe, Mn, Cu, and Pb, alkalinity, and pH	Baseline sampling: 07/21/05, 08/04/05, 08/24/05 Monthly sampling: 10/17/05, 11/21/05, 12/07/05, 01/19/06, 02/16/06, 03/15/06, 04/11/06, 05/10/06, 06/07/06, 07/19/06, 08/16/06, 09/12/06
Residual Solids	Adsorption Columns	6	Once (after media changeout)	TCLP metals, Al, As, Cd, Ca, Cu, Fe, Pb, Mg, Mn, Ni, P, Si, and Zn.	03/14/07[e]

(a) Abbreviations in parentheses corresponding to sample locations shown in Figure 4-4.
(b) See variations in Figure 3-1.
(c) Taken only at IN, OA, OB, and/or TC.
(d) Three baseline sampling events performed before system became operational.
(e) Media changed out on 03/14/07; columns shipped to ATS for sample collection on 6/5/07.
TCLP = Toxicity Characteristic Leaching Procedure; TDS = total dissolved solids; TOC = total organic carbon; LCR = lead and copper rule.

samples taken. To accommodate operator's schedules, holidays, and changes of sampling strategy when approaching the end of the study, the frequency of speciation sampling varied from once every two weeks to once every eight weeks, and the frequency of regular sampling events (i.e., with no speciation samples taken) varied from once a week to once every eight weeks (Figure 3-1).

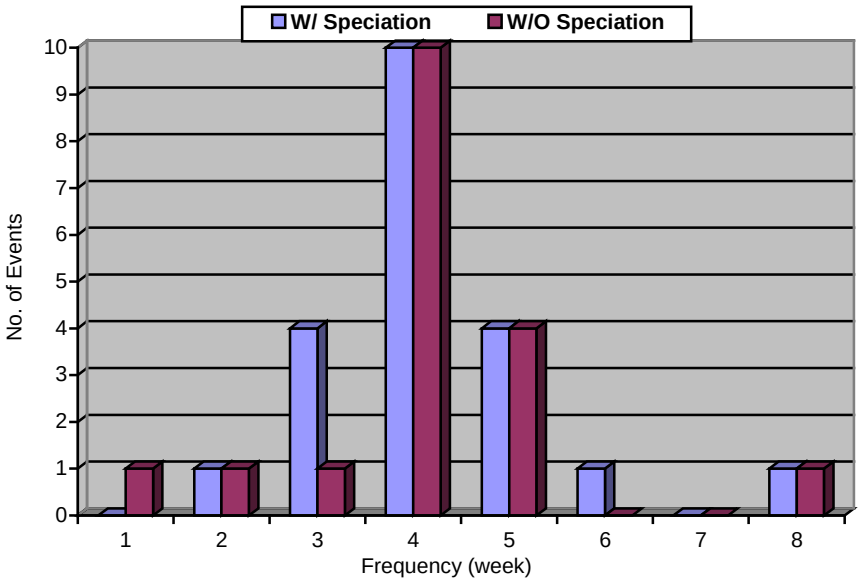


Figure 3-1. Sampling Frequency

Speciation samples were taken from IN, OA, OB, and TC during all speciation sampling events except for that taking place on September 19, 2005, with samples taken only from IN, OA, and TA; for that on November 29, 2005, with samples taken only from IN, OB, and TC; and for those on April 19, May 16, and June 13, 2007, with samples taken only from IN, OA, and OB. Samples taken during the speciation sampling events were analyzed onsite for pH, temperature, DO, and ORP, and off-site for total and soluble arsenic, iron, manganese, and aluminum as well as silica (Table 3-3). A number of exceptions occurred during the speciation sampling events and are summarized as follows:

- Onsite measurements were performed in only 12 out of 22 speciation sampling events.
- Total arsenic and silica were measured at all sampling locations for all speciation sampling events except for that on September 19, 2005, as noted above.
- Total iron, manganese, and aluminum were analyzed at all sampling locations for nine speciation sampling events on November 2, 2005, January 5, 2006, March 2 and 29, 2006, June 1 and 21, 2006, August 29, 2006, October 11, 2006, and March 7, 2007.
- Only arsenic speciation was performed for the last three speciation sampling events on April 19, 2007, May 16, 2007, and June 13, 2007.
- The list of analytes that should have been performed for a regular sampling event was inadvertently applied to the speciation sampling events on September 19, 2005, and August 29, 2006.

Water samples were taken from IN, OB, and TC during all regular sampling events except for that on October 17, 2005, with samples taken from IN, OA, TA, and TC. Similar to speciation samples, samples taken during the regular sampling events were analyzed both onsite and offsite for the analytes listed in Table 3-3. Several exceptions occurred during the regular sampling events and are summarized below:

- Onsite measurements were performed in only five out of 19 regular sampling events.
- Total arsenic and silica were measured at all sampling locations for all regular sampling events except for that on October 17, 2005, as noted above.
- Starting from October 26, 2006, the list of analytes was reduced to total arsenic, iron, manganese, and aluminum, silica, iodine, and alkalinity.
- Starting from January 18, 2007, the list of analytes was reduced to total arsenic, iron, manganese, and aluminum, and silica.
- EPA Method 300.0 with ion chromatography was used to measure iodine only once on October 17, 2005. Since then, inductively-coupled plasma-mass spectrometry (ICP-MS) was used as the replacement method for iodine analyses.

3.3.3 Residual Solids. Because the system did not require backwash, no backwash residuals were produced during system operations. Spent media samples were collected from the first two adsorption columns replaced on March 14, 2007. ATS collected one gallon of sample from each column and shipped the samples to Battelle. Approximately 200 g of the spent media from each container were collected after being homogenized and placed in one container. One aliquot was tested for TCLP. Another aliquot (approximately 100 g) was air-dried, crushed (using a mortar and pestle), acid digested, and analyzed for the analytes listed in Table 3-3.

3.3.4 Distribution System Water. Samples were collected from the distribution system to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, lead, and copper levels. Prior to system startup from July to August 2005, three sets of baseline distribution water samples were collected from three locations within the distribution system that were part of the historic sampling network under the Lead and Copper Rule (LCR). Following system startup, distribution system sampling continued on a monthly basis at the same locations for one year.

Samples were collected following an instruction sheet developed according to the *Lead and Copper Rule Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The dates and times of last water usage before sampling and sample collection were recorded, when possible, for calculating the stagnation time. All samples were collected from a cold-water faucet that had not been used for at least 6 hr to ensure that stagnant water was sampled.

3.4 Sampling Logistics

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method uses an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories according to the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2004).

3.4.2 Preparation of Sampling Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, colored-coded label consisting of the sample identification (ID), date and time of sample

collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles for each sampling locations were placed in separate Ziploc® bags and packed in the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/addressed FedEx air bills, and bubble wrap, were included. The chain-of-custody forms and air bills were complete except for the operator's signature and the sample dates and times. After preparation, the sample cooler was sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian verified that all samples indicated on the chain-of-custody forms were included and intact. Sample IDs were checked against the chain-of-custody forms, and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead.

Samples for metal analyses were stored at Battelle's ICP-MS laboratory. Samples for other water quality analyses by Battelle's subcontract laboratories, including American Analytical Laboratories (AAL) in Columbus, Ohio, Belmont Labs in Englewood, Ohio, and TCCI Laboratories (TCCI) in New Lexington, Ohio, were packed in separate coolers and picked up by a courier. Sulfide samples were packed in coolers and shipped via FedEx to DHL Laboratories in Round Rock, TX. The chain-of-custody forms remained with the samples from the time of preparation through collection, analysis, and final disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2004) were followed by Battelle ICP-MS, AAL, Belmont, TCCI, and DHL Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDLs), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The quality assurance (QA) data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a VWR Symphony SP90M5 Handheld Multimeter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Symphony SP90M5 probe in the beaker until a stable value was obtained.

Section 4.0: RESULTS AND DISCUSSION

4.1 Facility Description

The Richmond Elementary School is located at 700-585 Richmond Road in Susanville, CA, approximately 85 miles northwest of Reno, Nevada on U.S. 395. Prior to and during the EPA arsenic removal technology evaluation study, the school had approximately 250 students and staff members during the academic year. The school building was served by a single well (Well No. 2) operating at an estimated flowrate of 12 gpm. Figure 4-1 shows the pre-existing Well No. 2 pump house located near the southwest corner of the school building. Well No. 2 was 8-in in diameter and 145-ft deep with a screened interval extending from 75 to 145 ft below ground surface (bgs). The static water level was at approximately 20 ft bgs. Well No. 2 was equipped with a 1½ -horsepower Starite pump, operating for approximately 2.5 hr/day with an estimated maximum production rate of 2,000 gpd.

Figure 4-1. Preexisting Well No. 2 Pump House at Richmond Elementary School

There was no pre-existing treatment at the facility. Groundwater from Well No. 2 was pumped directly to three hydropneumatic tanks located in the pump house prior to the distribution system. Figure 4-2 shows the three pre-existing pressure tanks and related system piping.

4.1.1 Source Water Quality. Source water samples were collected on October 26, 2004, and subsequently analyzed for the analytes shown in Table 3-3. The results of the source water analyses, along with those provided by the facility to EPA for the demonstration site selection and those obtained from EPA and the California Department of Public Health (DPH), are presented in Table 4-1.

Total arsenic concentrations of source water ranged from 24.0 to 36.7 μg/L. Based on the October 26, 2004, sampling results, the total arsenic concentration in source water was 36.7 μg/L, of which 31.9 μg/L (or 87%) existed as soluble As(III) and 4.7 μg/L (or 13%) as soluble As(V). This speciation result was

Figure 4-2. Preexisting Pressure Tanks

consistent with the relatively low DO value of 1.0 mg/L measured during sampling. The ORP reading of 180 mV, however, was not as low as expected.

pH values of source water ranged between 7.0 and 8.5. The vendor indicated that the A/I Complex 2000 media could effectively remove arsenic as long as the pH values of source water were less than 9.0. As such, no pH adjustment was planned at this site.

Concentrations of iron (47 to 125 µg/L) in raw water were sufficiently low so pretreatment prior to the adsorption process was not required. Concentrations of orthophosphate and fluoride also were low (i.e., <0.1 and <0.2 mg/L, respectively) and, therefore, not expected to affect arsenic adsorption on the A/I Complex 2000 media. Silica concentrations were between 13.6 and 14.5 mg/L, similar to the level measured in source water at the Spring Brook Mobile Home Park (SBMHP) site in Wales, Maine (Lipps et al., 2006). Because the A/I Complex 2000 media was shown to be especially selective for silica at the SBMHP site, the effect of silica on arsenic adsorption was carefully monitored throughout the study period.

Other water quality parameters as presented in Table 4-1 had sufficiently low concentrations and, therefore, were not expected to affect arsenic adsorption on the A/I Complex 2000 media.

4.1.2 Distribution System. The original distribution system was installed in 1965 and was reported to consist of copper and galvanized iron piping. More recently, polyvinyl chloride (PVC) piping also was used. Compliance samples from the distribution system were collected every three years for metals and other analytes such as chloride, fluoride, nitrate, and nitrite. Under the EPA LCR, samples were collected from five taps within the school building every five years.

Table 4-1. Source Water Quality Data for Richmond Elementary School Site

Parameter	Unit	Facility Data	EPA Data	Battelle Data	California DPH Historic Data
Date			12/02/03	10/26/04	1994–2000
pH	S.U.	7	N/A	7.5	7.0–8.5
Temperature	°C	N/A	N/A	12.3	N/A
DO	mg/L	N/A	N/A	1.0	N/A
ORP	mV	N/A	N/A	180	N/A
Total Alkalinity (as $CaCO_3$)	mg/L	80	84	82	N/A
Hardness (as $CaCO_3$)	mg/L	48	44	40	N/A
Turbidity	NTU	N/A	N/A	0.9	N/A
TDS	mg/L	N/A	N/A	138	99–184
TOC	mg/L	N/A	N/A	1.0	N/A
Nitrate (as N)	mg/L	N/A	N/A	0.1	<2
Nitrite (as N)	mg/L	N/A	N/A	<0.01	<0.4
Ammonia (as N)	mg/L	N/A	N/A	<0.05	N/A
Chloride	mg/L	6	<5	2.1	1.3–6.0
Fluoride	mg/L	N/A	N/A	<0.1	0.1–0.2
Sulfate	mg/L	5	16.9	17.0	5.1–13.6
Silica (as SiO_2)	mg/L	N/A	13.6	14.5	N/A
Orthophosphate (as PO_4)	mg/L	N/A	0.08	<0.06	N/A
As (total)	µg/L	34	30	36.7	24–37
As (soluble)	µg/L	N/A	N/A	36.6	N/A
As (particulate)	µg/L	N/A	N/A	0.1	N/A
As (III)	µg/L	N/A	N/A	31.9	N/A
As(V)	µg/L	N/A	N/A	4.7	N/A
Fe (total)	µg/L	<100	47	125	<100
Fe (soluble)	µg/L	N/A	NA	<25	N/A
Mn (total)	µg/L	<20	5.5	5.6	<30
Mn (soluble)	µg/L	N/A	N/A	5.5	N/A
U (total)	µg/L	N/A	N/A	0.8	N/A
U (soluble)	µg/L	N/A	N/A	0.8	N/A
V (total)	µg/L	N/A	N/A	0.4	N/A
V (soluble)	µg/L	N/A	N/A	0.2	N/A
Na (total)	mg/L	66	27.2	35.0	N/A
Ca (total)	mg/L	14	14.2	11.2	N/A
Mg (total)	mg/L	4	2.1	2.9	N/A

N/A = not analyzed

4.2 Treatment Process Description

The ATS As/1200CS adsorption system used A/P Complex 2002 oxidizing media to oxidize As(III) to As(V) and then A/I Complex 2000 adsorptive media to adsorb As(V). The A/P Complex 2002 oxidizing media consisted of activated alumina and sodium metaperiodate and the A/I Complex 2000 adsorptive media consisted of activated alumina and a proprietary iron complex. Tables 4-2a and 4-2b present physical and chemical properties of the oxidizing and adsorptive media, respectively, provided by ATS. Both media have NSF International (NSF) Standard 61 listing for use in drinking water.

Table 4-2a. Physical and Chemical Properties of A/P Complex 2002 Oxidizing Media

Parameter	Value
Physical Properties	
Matrix	Activated alumina/metaperiodate complex
Physical form	Granular solid
Color	White granules
Bulk Density (lb/ft^3)	51
Specific Gravity (dry)	1.5
Hardness (lb/in^2)	14–16
Effective Size (mm)	0.42
Bulk Relative Density (g/cm^3)	0.90
BET surface area (m^2/g)	320
Attrition (%)	< 0.1
Moisture Content (%)	< 5
Particle Size Distribution (Tyler mesh)	28×48 (less than 2% fines)
Chemical Analysis	
Constituents	**Weight (%)**
Al_2O_3	96.59 (dry)
$NaIO_4$	3.41 (dry)

Source: ATS

Table 4-2b. Physical and Chemical Properties of A/I Complex 2000 Adsorptive Media

Parameter	Value
Physical Properties	
Matrix	Activated alumina/iron complex
Physical form	Granular solid
Color	Light brown/orange granules
Bulk Density (lb/ft^3)	51
Specific Gravity (dry)	1.5
Hardness (lb/in^2)	14–16
Effective Size (mm)	0.42
BET surface area (m^2/g)	320
Attrition (%)	< 0.1
Moisture Content (%)	< 5
Particle Size Distribution (Tyler mesh)	28×48 (<2% fines)
Chemical Analysis	
Constituents	**Weight (%)**
Al_2O_3	90.89 (dry)
$NaIO_4$	3.21 (dry)
$Fe(NH_4)_2(SO_4)_2 \bullet 6H_2O$	5.90 (dry)

Source: ATS

The ATS As/1200CS system was a fixed-bed downflow adsorption system designed for use at small water systems with flowrates of around 12 gpm. When a column reaches capacity, the column with spent media is removed, dewatered, and shipped to ATS' shop in Massachusetts. After being subjected to the EPA TCLP test, the spent media was either disposed of or recycled for beneficiary use.

The system at the Richmond Elementary School was configured in series. The system was designed to allow the lead column to be removed upon exhaustion and each of the two lag columns to be moved forward one position (i.e., the first lag column became the lead column, and the second lag column

became the first lag column). A new column loaded with virgin media was then placed at the end of the treatment train. Figure 4-3 shows a schematic diagram of the system.

The major system components are described as follows:

- **Pressure Tanks.** Two pre-existing Model WX-252 and one pre-existing Model WX-302 Well-X-TROL tanks by AMTROL with a total storage capacity of approximately 250 gal were located at the system inlet. These pressure tanks served as a temporary storage for well water. The well pump was turned on when the pressure in the tanks had dropped to below 40 pounds per square inch (psi) and the well pump was turned off after the tanks had been refilled and the pressure in the tanks had reached 62 psi.

- **Sediment Filter.** One 25-µm sediment filter was installed at the head of the treatment train. The 6-in × 20-in filter was used to remove sediment and avoid introducing large particles directly into the oxidation and adsorption columns.

- **Oxidation Columns.** Following the sediment filter were two 10-in × 54-in sealed polyglass columns (by Park International) each loaded with 1.5 ft^3 of A/P Complex 2002 oxidizing media. Each oxidation column had a riser tube and a valved head assembly to control inflow, outflow, and by-pass.

- **Adsorption Columns.** Following the two oxidation columns were three 10-in × 54-in sealed polyglass columns (by Park International) each loaded with 1.5 ft^3 of A/I Complex 2000 adsorptive media. Similar to the oxidation columns, each adsorption column had a riser tube and a valved head assembly to control inflow, outflow, and by-pass.

- **Totalizer/Flow Meter.** One Model F-1000 paddlewheel totalizer/flow meter (by Blue-White Industries) was installed on the downstream end of the treatment train to record the flowrate and volume of water treated through the treatment train.

- **Booster Pump and Pressure Tank**. One 180-gal Well-Rite pressure tank (by Flexcon Industries in Randolph, Maine) fitted with a ¾-hp Goulds booster pump (Model No**.** C48A94A06) was installed at the system outlet. The booster pump/pressure tank was used to "pull" water from the three pressure tanks at the system inlet through the two oxidation and three adsorption columns; provide temporary storage of the treated water; and supply the treated water with the needed pressure to the distribution system. The on/off of the booster pump was controlled by the low/high pressure switch set at 45/65 psi on the pressure tank.

- **Pressure Gauges.** One each BII (0-100 psi) pressure gauge was installed at the system inlet just prior to the sediment filter, at the head of each column, and at the system outlet. The pressure gauges were used to monitor the system pressure and pressure drop across the treatment train.

- **Sampling Taps.** Sampling taps made of PVC (by US Plastics) were located prior to the system and following each oxidation and adsorption vessel for water sampling.

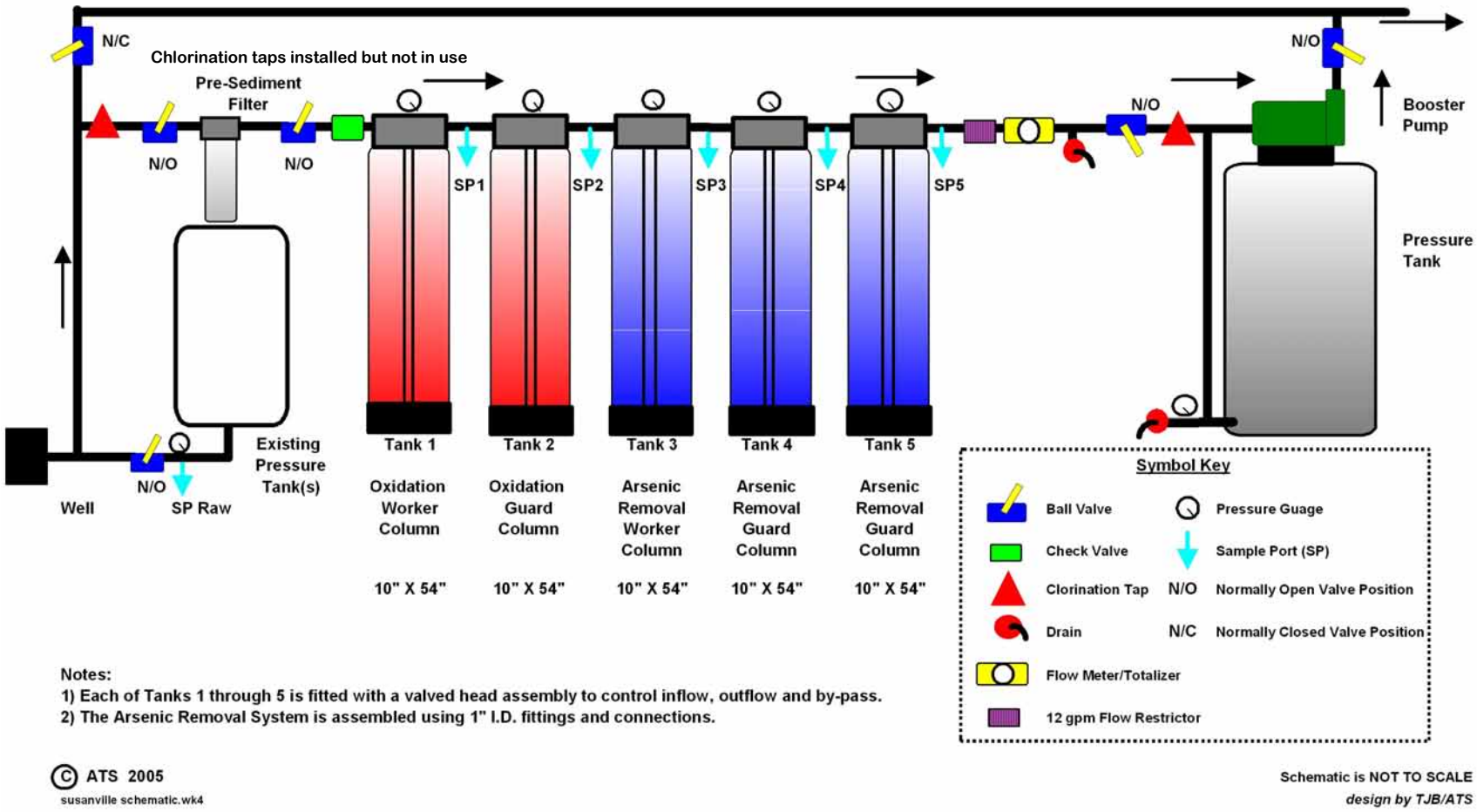


Figure 4-3. Schematic of ATS As/1200CS System

The system was constructed using 1-in copper piping and fittings. The design features of the treatment system are summarized in Table 4-3, and a flow diagram along with the sampling/analysis schedule are presented in Figure 4-4. A photograph of the system installed is shown in Figure 4-5 and a close-up view of the oxidation and adsorptive media columns is shown in Figure 4-6.

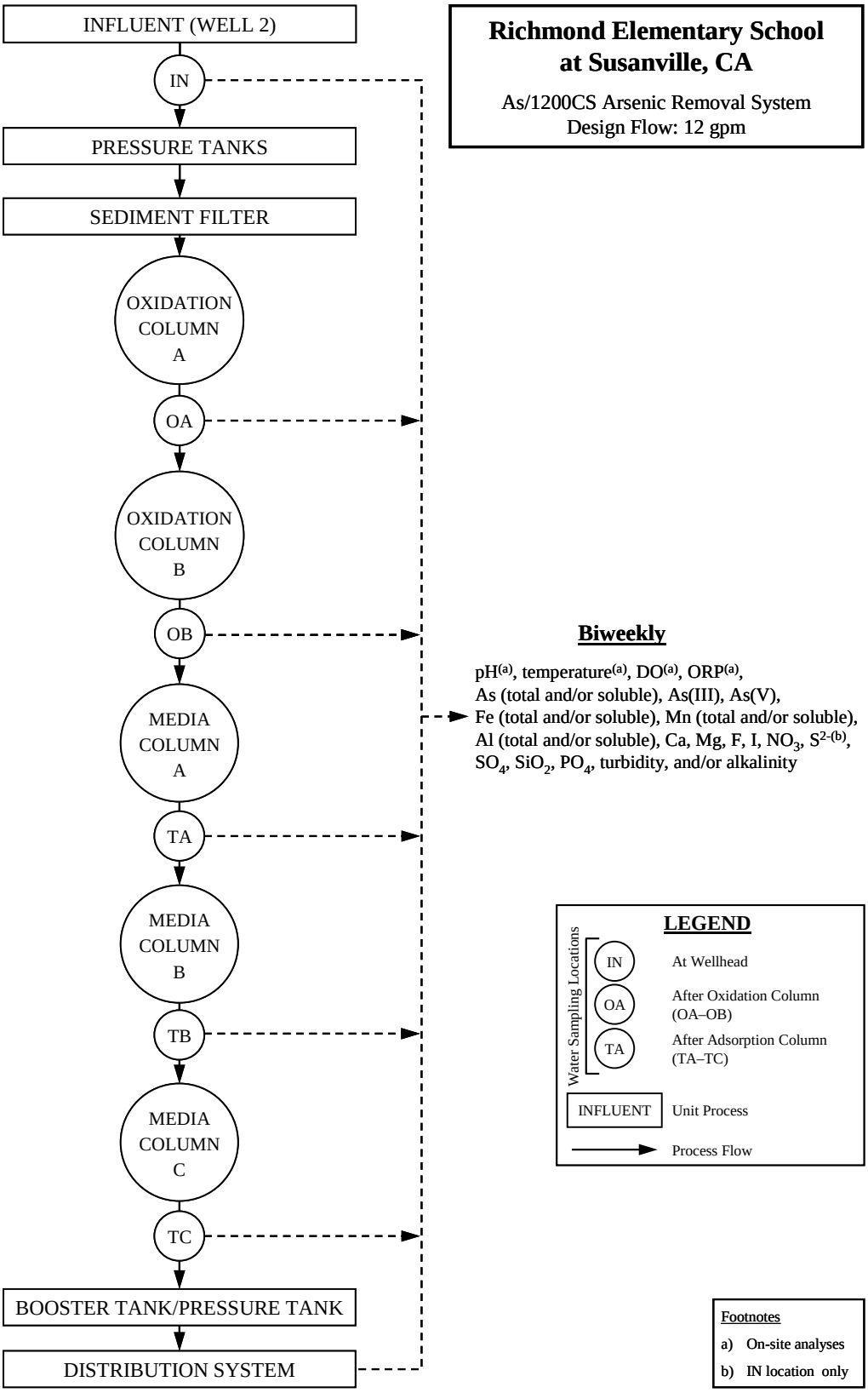
Table 4-3. Design Specifications of ATS As/1200CS System

Parameter	Value	Remarks
Oxidation Columns		
Column Size (in)	10 D × 54 H	-
Cross-Sectional Area (ft^2/column)	0.54	-
Number of Columns	2	-
Configuration	Series	-
Media Type	A/P Complex 2002	See Table 4-2a
Media Quantity (lbs/column)	76.5	
Media Volume (ft^3/column)	1.5	
Adsorption Columns		
Column Size (in)	10 D × 54 H	-
Cross-Sectional Area (ft^2/column)	0.54	-
Number of Columns	3	-
Configuration	Series	-
Media Type	A/I Complex 2000	See Table 4-2b
Media Quantity (lbs/column)	76.5	
Media Volume (ft^3/column)	1.5	
Service		
System Flowrate (gpm)	12	-
Hydraulic Loading Rate (gpm/ft^2)	22	-
EBCT (min/column)	0.9	2.7 min for 3 adsorption columns
Maximum Use Rate (gpd)	2,000	Estimate provided by school
Estimated Working Capacity (BV)	42,720	To breakthrough at capacity from lead column
Throughput to Breakthrough (gal)	479,000	Based on 1.5 ft^3 of media in lead column
Estimated Media Life (months)	8	Based on maximum use rate of 2,000 gpd
Backwash	-	No system backwash required

4.3 Permitting and System Installation

Engineering plans for the system were prepared by ATS and reviewed by NST Engineering, Inc. The plans consisting of a schematic and a written description of the As/1200CS system were submitted to California DPH for approval on July 29, 2005. The approval was granted by the California DPH on August 24, 2005.

The system was placed in the existing treatment building, shown in Figure 4-1, without any addition or modifications. The As/1200CS system, consisting of factory-packed oxidation and adsorption columns and pre-assembled system valves, gauges, and sample taps, was shipped by ATS and delivered to the site on August 15, 2005. The system installation began that same day, including some re-work of the existing system piping. The sediment filter was attached to the wall at the head of the treatment train (Figure 4-5). The media columns were then set into place and plumbed together using copper piping and connections. The mechanical installation was complete on August 16, 2005. Before the system was put online, the system piping was flushed and the columns were filled one at a time to check for leaks. Once all columns were filled, the system was operated for a short period with the treated water discharged to the sewer.



Note: Analyses reduced after approximately one year of sampling

Figure 4-4. Process Flow Diagram and Sampling Locations

Figure 4-5. Oxidation and Adsorption Columns Shown Against Wall and a Sediment Filter Attached to Wall

Figure 4-6. Close-up View of Oxidation and Adsorption Columns with Sample Taps and Labels

After it was determined that the system had been operating properly, the system and new pipe were disinfected according to American Water Works Association (AWWA) Standard C651-99 and a sample was collected for the total coliform test. The system was bypassed until August 30, 2005, when the satisfactory total coliform sample results were obtained. The first set of samples was collected on September 19, 2005, after the system was put online.

Several punch-list items were identified by Battelle during a site visit on September 19, 2005, when the system was inspected and operator training conducted. The punch-list items consisted of the following:

- A totalizer/flowmeter was installed after the booster pump/pressure tank following the As/1200CS system and measured only the flowrates from the pressure tank to the distribution. A second totalizer/flowmeter placed just prior to the booster pump/pressure tank was required to measure the flowrates and volume of water treated by the system. The totalizer/flowmeter was installed on December 4, 2005.
- An hour meter was installed on the well pump rather than the booster pump. The wellhead hour meter tracked the amount of time that the well pump operated rather than the system. A second hour meter on the booster pump was therefore required to determine the amount of time that the system operated. The hour meter was installed on December 9, 2005.
- A check valve was installed on a line that bypassed the booster pump/pressure tank assembly from the adsorption columns to the distribution system. The check valve must be replaced with a ball valve to ensure proper system operations.

4.4 System Operation

4.4.1 Operational Parameters. The operational parameters of the system are tabulated and attached as Appendix A. Key parameters are summarized in Table 4-4. From September 7, 2005, through June 13, 2007, Well No. 2 operated for a total of only 238 hr, or 0.1 to 2.1 hr/day, based on hour meter readings on the well pump. The operational time represented a utilization rate of approximately 2.5% (on average) over the 21-month evaluation period with the well pump operating for an average of 0.6 hr/day. A total of 415 days when the school was in session and when maintenance occurred in the summer of 2006 was used for calculations. The 415 school days do not include weekends, holidays, spring breaks, and Christmas break.

Table 4-4. Summary of As/1200CS System Operations

Operational Parameter	Value
Operation Duration	09/07/05–06/13/07
Total Well Operating Time (hr)	238
Total Booster Pump/Treatment System Operating Time (hr)	442
Total Number of School Days (day)[(a)]	415
Well No. 2 Operating Time (hr/day)	0.1–2.1 (0.6)
Booster Pump/Treatment System Operating Time (hr/day)	0.1–4.6 (1.1)
Volume Throughput (gal)	302,960
Well No. 2 Flowrate (gpm)[(b)]	4.2–48.6 (21.6)
Booster Pump/Treatment System Flowrate (gpm)[(c)]	4.6–32.0
Daily Use Rate (gpd)	39–2,613 (730)
EBCT (min/column)	0.7–1.6 (1.2)
Range of Influent Pressure (psi)	31–64 (48)
Average Pressure in Each Column (psi)[(d)]	48, 45, 39, 32, 23, 18
Average Pressure Loss across Each Column (psi)	6.1

(a) Less weekends, holidays, spring breaks, and Christmas break plus days when maintenance occurred in summer.
(b) Calculated based on totalizer and well pump hour meter readings.
(c) Calculated based on totalizer and booster pump hour meter readings; see Figure 4-7 for unexpected flowrate increase.
(d) Pressure readings at IN, OA, OB, TA, TB, and TC, respectively.
Numeric figures in parentheses denote average.

Based on totalizer and well pump hour meter readings, calculated Well No. 2 flowrates ranged from 4.2 to 48.6 gpm and averaged 21.6 gpm (excluding three outliers – 61.5, 134.9, and 1.6 gpm observed on February 9, 2006; May 3, 2006; and March 8, 2007, respectively). As denoted by "♦" in Figure 4-7, the well pump flowrates fluctuated around the average value throughout the course of the evaluation and did not appear to be affected by the relocation of a 75-gal pressure tank from before to after the treatment system approximately 12.5 months into system operations. (Note that the relocation decreased the storage capacity of raw water before treatment and increased correspondingly the storage capacity of treated water after treatment.) The average well pump flowrate was almost two times the flowrate provided by the school during the introductory meeting in October 2004. No pump curve was available prior to the system installation.

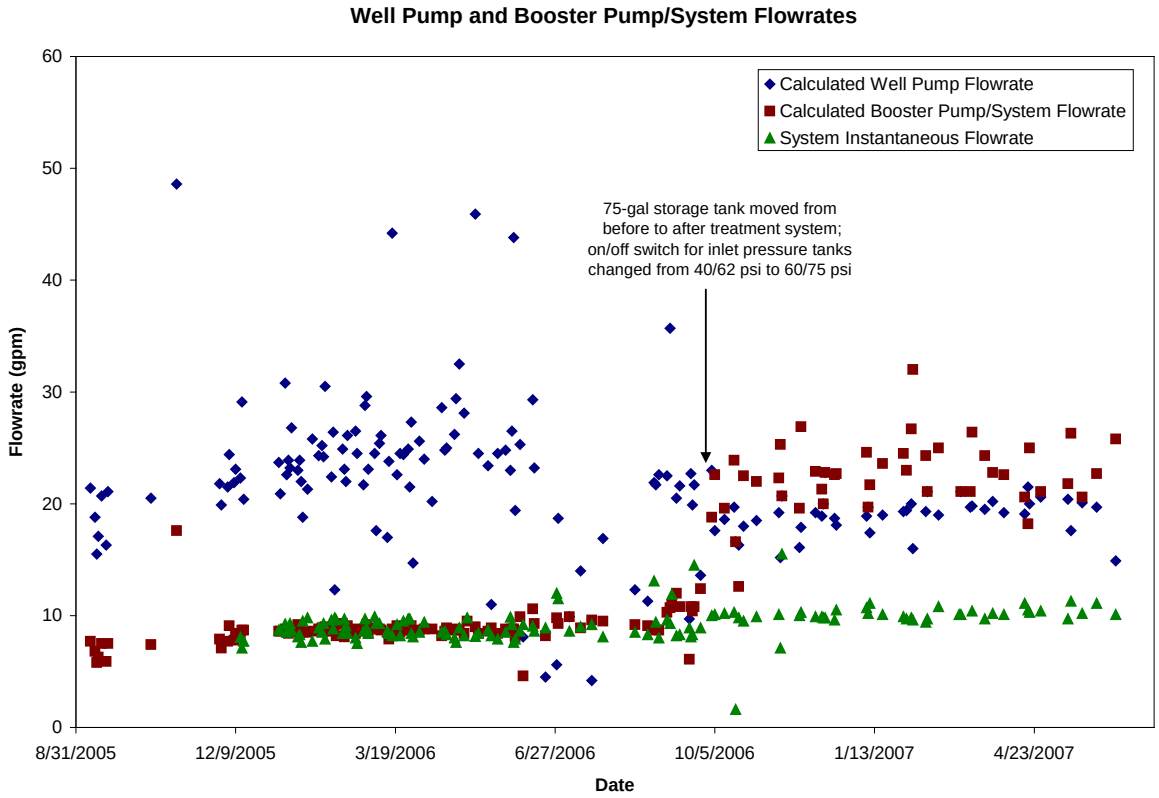


Figure 4-7. Variation of Booster Pump/System Flowrates

The booster pump and the treatment system operated for 442 hr based on hour meter readings of the booster pump. Note that before the hour meter was installed on the booster pump on December 9, 2005, the booster pump run times were estimated by multiplying respective well pump run times by a factor of 2.77, which is the ratio of the total booster pump run time to total well pump run time during the six-month period following the installation of the hour meter. The daily operational time of the booster pump and the system ranged from 0.1 to 4.6 hr/day, averaged 1.1 hr/day. The operational time represented a utilization rate of approximately 4.6%. Again, a total of 415 school days was used for calculations.

Calculated booster pump/treatment system flowrates, denoted by "■," ranged from 4.6 to 12.4 gpm (except for one outlier at 17.6 gpm) and averaged 8.8 gpm during the first 12.5 months of system operations, but rose unexpectedly to levels ranging from 12.6 to 32.0 gpm (excluding one outlier 1.9 gpm observed on March 7, 2007) and averaging 22.3 gpm through the remainder of the evaluation. The

sudden increase in flowrate from 8.8 to 22.3 gpm (on average) coincided with the above-mentioned relocation of a 75-gal pressure tank in September 2006, although no plausible explanation might link the event to the observed increase. Because a 12-gpm flow restrictor had been installed on the treatment system since system startup, flowrates above 12 gpm were suspect. This conclusion was further supported by the relatively constant instantaneous flowrate readings, denoted by "▲," taken from the flow meter/totalizer installed on the treatment system, which ranged from 7.1 to 15.5 gpm (except for one outlier at 1.6 gpm) and averaged 9.3 gpm throughout the study period. Because these values were very close to the calculated flowrates before pressure tank relocation, instantaneous flowrate readings were used to represent system flowrates.

The empty bed contact time (EBCT) for each column ranged from 0.7 and 1.6 min and averaged 1.2 min (or 3.6 min [on average] if considering the three adsorption columns as one large column). These values are 33% higher than the design value of 0.9 min per column or 2.7 min for three columns. Based on the average flowrate and average daily operating time, the average daily use rate was about 730 gpd (assuming 415 school days), which was about 37% of the estimate provided by the school.

The total system throughput during this 21 month period was approximately 302,960 gal. This corresponds to 27,000 BV of water processed through a column containing 1.5 ft^3 (or 11.2 gal) of media. For the three columns in series with 4.5 ft^3 of media, the system treated approximated 9,000 BV of water.

The pressure loss across each column ranged from 0 to 17 psi and averaged 6.1 psi. The total pressure loss across the treatment train (five columns in series) averaged 30 psi. The average influent pressure at the head of the system from the wells was 47.6 psi, and the average pressure following the last column in each treatment train was 17.5 psi. The booster pump and pressure tank installed after the system provided 52.4 psi of pressure to the distribution system.

4.4.2 Residual Management. The only residual produced by the operation of the As/1200CS treatment system was spent media. The first two adsorption columns were replaced on March 14, 2007, after approximately 18 months of system operations. Because the oxidation columns were effectively reducing As(III) to As(V) throughout the evaluation period, they were not replaced. The system did not require backwashing to operate and therefore no backwash residual was produced.

4.4.3 System Operation, Reliability and Simplicity. The system encountered some operational difficulties soon after it began operation. On several occasions, the 180-gal pressure tank located at the system outlet did not provide sufficient water to meet the peak demand of the school. On September 25, 2006, the system operator moved one of the three 75-gal pressure tanks located at the system inlet to after the treatment system to provide extra treated water storage.

4.4.3.1 Pre- and Post-Treatment Requirements. The only pretreatment step was the oxidation of As(III) to As(V) via the oxidizing media installed in the first two columns of the treatment train. No additional chemical addition or other pre- or post-treatment steps were used at the site.

4.4.3.2 System Controls. The As/1200CS adsorption system was a passive system, requiring only the operation of the supply well pump and booster pump to send water to the two pressure tanks at the system inlet and through the oxidation and adsorption columns to the two pressure tanks at the system outlet (this was changed from three pressure tanks at the system inlet and one pressure tank at the system outlet as discussed above). The media columns themselves did not have automated parts and all valves were manually activated. The inline flowmeter was battery powered so that the only electrical power required was that needed to run the supply well pump and booster pump. The supply well pump was in place prior to the installation of the ATS treatment system. The system operation was controlled by the pressure switches in the pressure tank at the system outlet.

4.4.3.3 Operator Skill Requirements. Under normal operating conditions, the skills required to operate the As/1200CS system were minimal. The operation of the system did not appear to require additional skills beyond those necessary to operate the existing water supply system in place at the site.

The treatment facility was considered by the California DPH as a non-transient, non-community water system. Because it served more than 25 of the same people for more than 60 days a year, it was considered a public water system. All individuals who operate or supervise the operation of a public water system in the state of California must possess a water treatment operator certificate. An individual who makes decisions addressing the operational activities must possess a distribution operator certificate. The operational activities are described in Title 22, Division 4, Chapter 13, Subsection 63770(b) of the California Code of Regulations (CCR, 2001).

Operator certifications are granted by the State of California after meeting minimum requirements, which include passing an examination and maintaining a minimum amount of hours of specialized training. There are five grades of operators for both water treatment (T1-T5) and distribution (D1-D5). Because the Richmond Elementary School has a simple water system and serves a population of less than 1,000, it qualifies as a Grade 1 (the lowest) for both treatment and distribution. The school operator possesses a T1 and D1 certification.

4.4.3.4 Preventative Maintenance Activities. The only regularly scheduled preventative maintenance activity recommended by ATS was to inspect the sediment filters monthly and replace as necessary. The treatment system operator visited the site about three times per week (approximately 20 min) to check the system for leaks, and record flow, volume, and pressure readings.

4.5 System Performance

The system performance was evaluated based on analyses of samples collected from the raw and treated water from the treatment and distribution systems. The system ran from September 7, 2005, through June 13, 2007. On March 14, 2007, the first two adsorption columns were removed; the third adsorption column was moved to the lead position; and two new adsorption columns were placed at the end of the treatment train. Evaluation of the treatment system was based on the original oxidation and adsorption columns installed.

4.5.1 Treatment Plant Sampling. Table 4-5 summarizes the arsenic, iron, manganese, and aluminum results from samples collected throughout the treatment plant. Table 4-6 summarizes the results of other water quality parameters. Appendix B contains a complete set of analytical results through the 21 months of system operations. The results of the treatment plant sampling are discussed below.

4.5.1.1 Arsenic and Iodine. The key parameter for evaluating the effectiveness of the treatment system was the concentration of arsenic in the treated water. The treatment plant water was sampled on 44 occasions during the evaluation period (with duplicates taken on three and speciation performed on 22 of the 44 occasions).

Figure 4-8 contains four bar charts each showing the concentrations of total arsenic, particulate As, soluble As(III), and soluble As(V) at the wellhead, after the first and second oxidation columns and after the entire system. Total arsenic concentrations in raw water ranged from 25.1 to 35.4 µg/L and averaged 31.7 µg/L (Table 4-5). For the first two months of the performance evaluation study, soluble As(III) was the predominating species in raw water with concentrations averaging 28.4 µg/L. Soluble As(III) concentrations decreased after the third month of operation for unknown reasons and remained below 47% of the soluble arsenic throughout the remainder of the evaluation period (Figure 4-8) with

Table 4-5. Summary of Arsenic, Iron, Manganese, and Aluminum Analytical Results

Parameter	Sampling Location	Number of Samples	Concentration (µg/L)			Standard Deviation
			Minimum	Maximum	Average	
As (total)	IN	44[a,c]	25.1	35.4	31.7	2.1
	OA–OB	42–44[a,d]	(b)			
	TA–TC	37–43[a,d]				
As (particulate)	IN	21[c]	<0.1	8.3	0.8	1.8
	OA–OB	21	(b)			
	TA–TC	0–17[d]				
As (III)	IN	21[c]	6.2	28.5	12.1	6.0
	OA–OB	21	(b)			
	TA–TC	0–17[d]				
As (V)	IN	21[c]	3.4	27.8	19.8	6.2
	OA–OB	21	(b)			
	TA–TC	0–17[d]				
Fe (total)	IN	41[a]	<25	136	36.7	25.9
	OA–OB	21–39[a,d]	<25	<25	<25	0.0
	TA–TC	11–38[a,d]	<25	<25	<25	0.0
Fe (soluble)	IN	19	<25	41.1	<25	9.5
	OA–OB	18	<25	<25	<25	0.0
	TA–TC	0–17[d]	<25	<25	<25	0.0
Mn (total)	IN	41[a]	3.5	7.7	5.4	0.9
	OA–OB	21–39[a,d]	<0.1	0.5	<0.1	0.1
	TA–TC	11–38[a,d]	<0.1	0.8	<0.1	0.1
Mn (soluble)	IN	19	3.5	7.5	5.2	1.0
	OA–OB	18	<0.1	0.3	<0.1	0.1
	TA–TC	0–18[d]	<0.1	0.3	<0.1	0.1
Total Al	IN	41[a]	<10	<10	<10	0.0
	OA–OB	20–39[a,d]	13.9	36.2	23.5	4.9
	TA–TC	9–38[a,d]	17.5	40.9	26.6	5.7
Soluble Al	IN	19	<10	<10	<10	0.0
	OA–OB	18	14.2	35.4	23.3	5.4
	TA–TC	0–16[d]	13.9	38.6	26.5	6.8

One-half of detection limit used for calculations involving non-detect samples.
Duplicate samples included in calculations.
(a) Including three duplicate samples
(b) Statistics not provided; see Figure 4-10 for As breakthrough curves.
(c) Outlier removed from statistical analysis
(d) Figures shown reflect range of sampling occasions taking place at specified sampling locations.

concentrations ranging between 6.2 and 15.0 µg/L (excluding one outlier on April 27, 2006) and averaging 10.4 µg/L. Soluble As(V) concentrations ranged from 3.4 to 27.8 µg/L and averaged 19.8 µg/L. Particulate arsenic was low with concentrations typically less than 1 µg/L. The influent arsenic concentrations measured during this 21-month period were consistent with those in the raw water sample collected on October 26, 2004 (Table 4-1), except for the lower levels of As(III) measured during the majority of the evaluation period from November 2005 through June 2007.

Oxidation of As(III) to As(V) within the oxidation columns was achieved via reactions with sodium metaperiodate, a key ingredient loaded on the A/P Complex 2002 oxidizing media for As(III) oxidation (Table 4-2a). At a pH value between 8.0 to 8.8 (as measured for raw water in Table 4-6), metaperiodate presumably reacted with H_3AsO_3 following Equation 1:

$$IO_4^- + 4H_3AsO_3 \rightarrow I^- + 4HAsO_4^{2-} + 8H^+ \quad (1)$$

Table 4-6. Summary of Water Quality Parameter Measurements

Parameter	Sampling Location	Unit	Number of Samples	Concentration/Standard Unit			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity (as $CaCO_3$)	IN	mg/L	24[a]	83	121	91.0	7.3
	OA–OB	mg/L	2–22[a,d]	79	118	91.2	8.1
	TA–TC	mg/L	0–22[a,d]	79	101	88.8	4.9
Fluoride	IN	mg/L	16[a]	0.1	0.2	0.2	0.05
	OA–OB	mg/L	2–15[a,d]	0.1	0.3	0.2	0.06
	TA–TC	mg/L	0–16[a,d]	<0.1	0.3	0.2	0.10
Sulfate	IN	mg/L	16[a]	15	23	17.5	2.1
	OA–OB	mg/L	2–15[a,d]	16	22	18.1	1.6
	TA–TC	mg/L	0–16[a,d]	16	23	18.7	1.9
Iodine (as I)	IN	mg/L	17[b]	0.5	24.5	6.4	6.7
	OA–OB	mg/L	1–16[b,d]	16.2	256	95.7	88
	TA–TC	mg/L	1–17[b,d]	26.1	707	159	211
Phosphorus (as P)	IN	mg/L	18[a]	<10	32.4	<10	7.6
	OA–OB	mg/L	4–18[a,d]	<10	29.8	<10	7.3
	TA–TC	mg/L	2–18[a,d]	<10	15.5	<10	3.4
Silica (as SiO_2)	IN	mg/L	41[a]	12.8	15.7	14.1	0.6
	OA–OB	mg/L	40–42[a,d]	5.6	15.7	11.3	1.8
	TA–TC	mg/L	38–41[a,d]	2.2	15.1	7.8	2.7
Nitrate (as N)	IN	mg/L	16[a]	<0.05	0.40	0.07	0.11
	OA–OB	mg/L	2–15[a,d]	<0.05	0.20	<0.05	0.05
	TA–TC	mg/L	0–16[a,d]	<0.05	0.10	<0.05	0.03
Turbidity	IN	NTU	17[a]	0.2	1.9	0.9	0.5
	OA–OB	NTU	2–15[a,d]	<0.1	2.3	0.8	0.6
	TA–TC	NTU	0–15[a,d]	0.2	2.7	0.9	0.8
pH	IN	S.U.	17	8.0	8.8	8.4	0.2
	OA–OB	S.U.	13–17[d]	7.7	8.4	8.1	0.2
	TA–TC	S.U.	0–15[d]	7.4	8.2	7.7	0.2
Temperature	IN	°C	17	11.4	17.6	14.7	1.6
	OA–OB	°C	13–17[d]	11.6	17.9	15.0	1.6
	TA–TC	°C	0–15[d]	12.5	18.3	14.8	1.6
DO	IN	mg/L	12[c]	0.3	3.0	1.4	0.8
	OA–OB	mg/L	8–12[c,d]	0.4	2.6	1.2	0.7
	TA–TC	mg/L	0–10[c,d]	0.3	2.8	1.3	0.9
ORP	AC	mg/L	16	134	348	246	57
	OA–OB	mg/L	12–16[d]	141	323	248	45
	TA–TC	mg/L	0–14[d]	135	609	251	100
Total Hardness (as $CaCO_3$)	IN	mg/L	16[a]	33.2	50.8	43.0	4.9
	OA–OB	mg/L	3–14[a,d]	31.3	50.7	42.7	5.8
	TA–TC	mg/L	0–15[a,d]	31.1	58.7	43.4	8.0
Ca Hardness (as $CaCO_3$)	IN	mg/L	16[a]	25.1	42.3	33.9	4.6
	OA–OB	mg/L	3–14[a,d]	23.5	40.2	33.6	5.3
	TA–TC	mg/L	0–15[a,d]	23.4	48.0	35.0	7.4
Mg Hardness (as $CaCO_3$)	IN	mg/L	16[a]	7.7	11.3	9.1	1.0
	OA–OB	mg/L	3–14[a,d]	7.7	10.5	8.8	0.9
	TA–TC	mg/L	0–15[a,d]	7.7	11.7	8.9	1.1

One-half of detection limit used for calculations involving non-detect samples.
Duplicate samples included in calculations.
Figures shown under "Number of Samples" reflect range of samples taken at specified sampling locations.
(a) Including three duplicate samples.
(b) Including two duplicate samples.
(c) Outliers removed from statistical analysis.
(d) Figures shown reflect range of sampling occasions taking place at specified sampling locations.

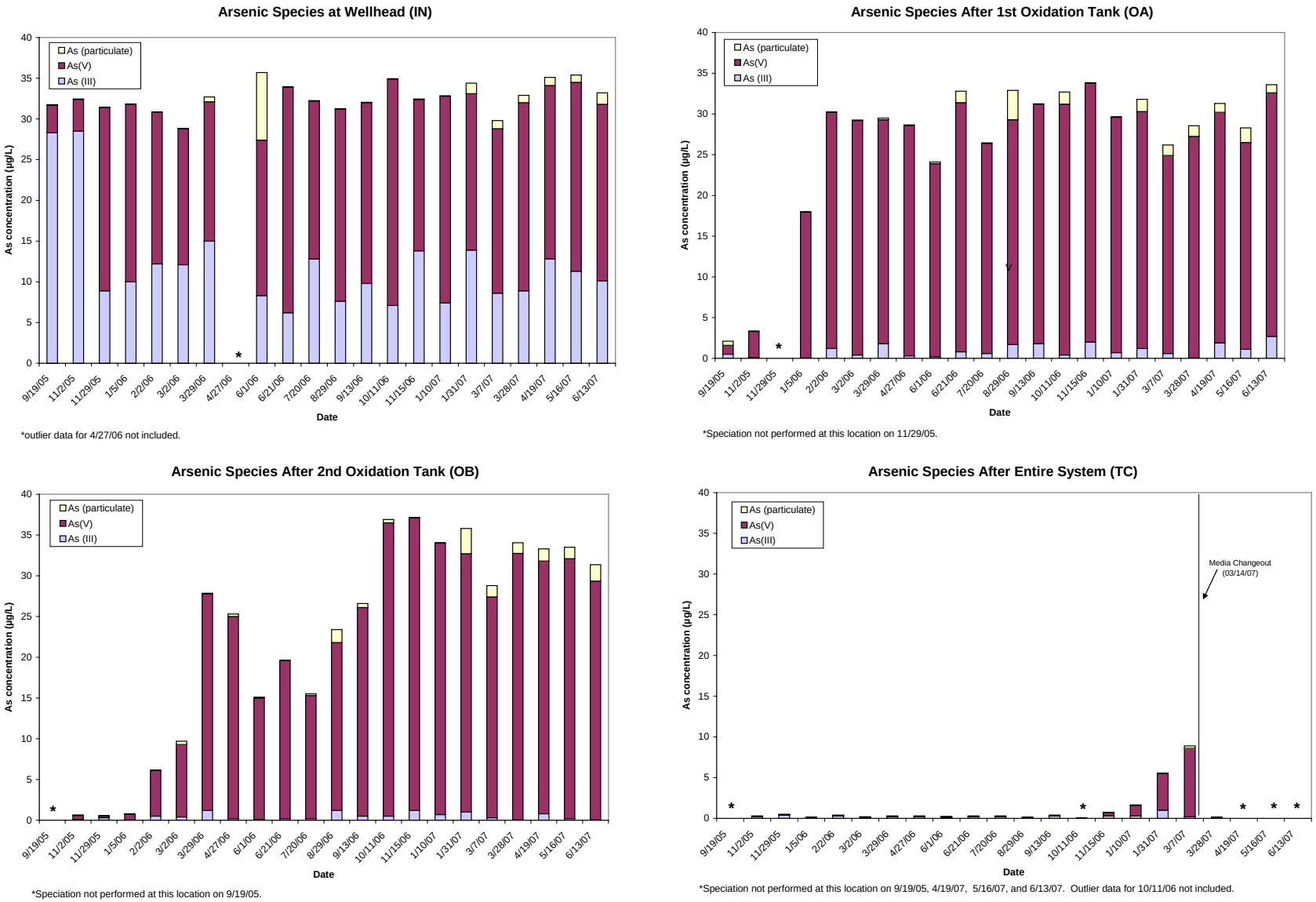


Figure 4-8. Concentrations of Particulate Arsenic, Soluble As(III), and Soluble As(V) across Treatment System

Meanwhile, metaperiodate would react with any soluble iron, existing as Fe(II), and with soluble manganese, existing as Mn(II), in raw water following Equations 2 and 3:

$$IO_4^- + 8Fe^{2+} + 8H^+ \rightarrow I^- + 8Fe^{3+} + 4H_2O \quad (2)$$

$$IO_4^- + 4Mn^{2+} + 4H_2O \rightarrow I^- + 4MnO_2 + 8H^+ \quad (3)$$

To oxidize the As(III), Fe(II), and Mn(II) in raw water, only 9.6 µg/L of I^- would have been produced stoichiometrically and leached into the column effluent. This amount is lower than the analytical reporting limit of 200 µg/L for I^- by EPA Method 300.0 by ion chromotagraphy. This observation is consistent with the analytical results (<200 µg/L of I^-) reported for the samples collected at the wellhead, after the oxidation columns, and after the adsorption columns on October 17, 2005.

Total iodine also was analyzed using ICP-MS on 17 occasions (including two duplicates) during the evaluation period. Iodine concentrations following the oxidation and adsorption columns averaged 95.7 and 159 µg/L [as I], respectively, which were significantly higher than those measured in raw water (averaging 6.4 µg/L [as I]). Because only 9.6 µg/L of total iodine would have existed as I^-, the iodine present in the column effluent most likely was IO_4^- or other reaction intermediates. It was possible that some IO_4^- leached from the oxidizing media, but the leaching followed an apparent decreasing trend as shown in Figure 4-9. Iodine concentrations in the treated water were gradually reduced from as high as 264 to <45 µg/L [as I] about four months before rebedding.

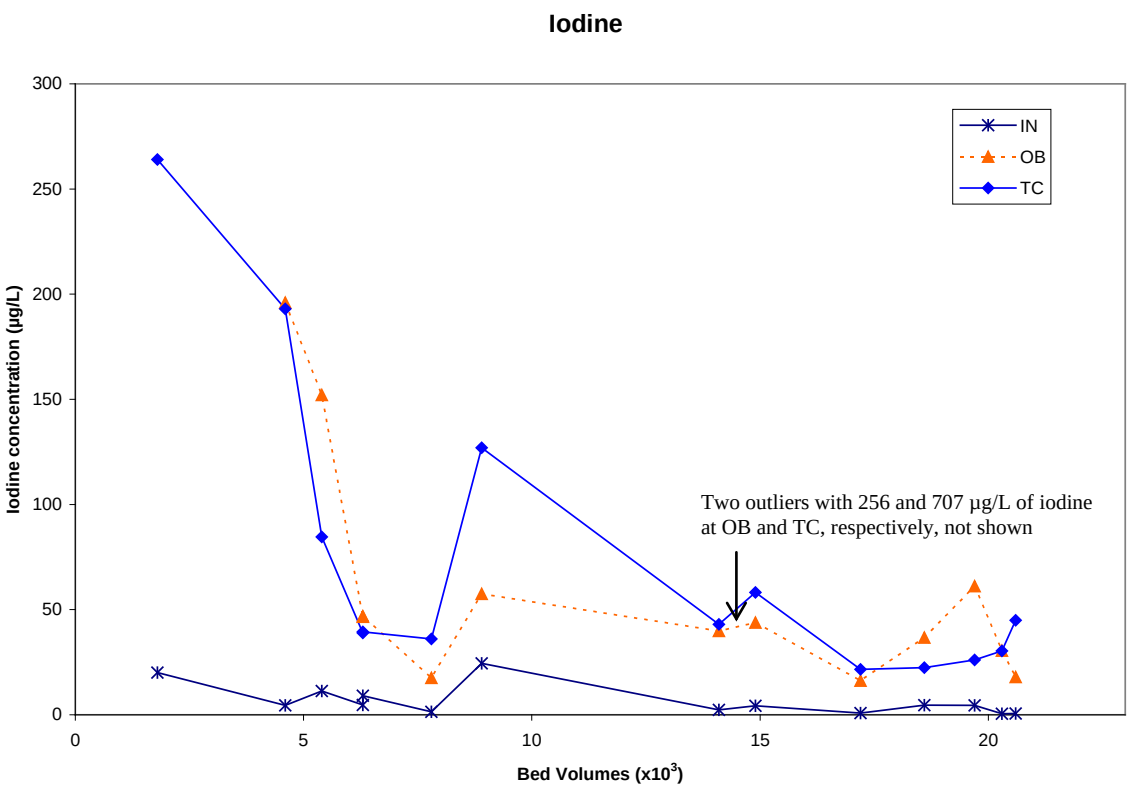


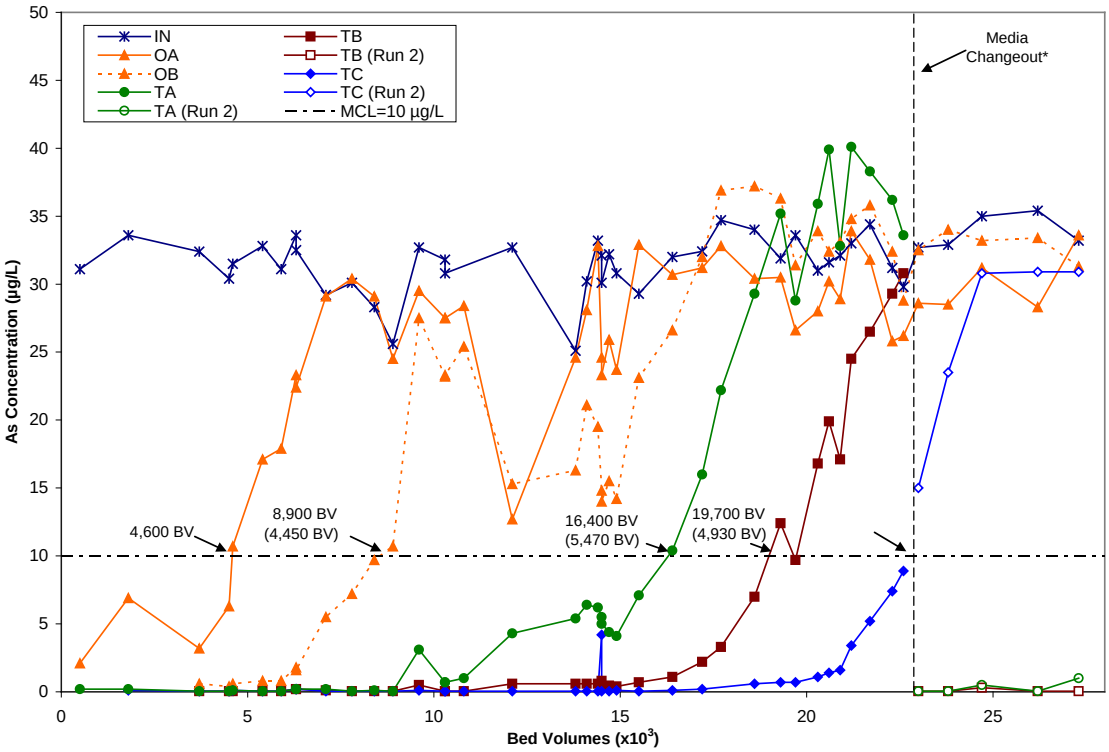
Figure 4-9. Iodine Concentrations across Treatment Train (BV Calculations Based on 1.5 ft³ of Media in Each Column)

As(III) was effectively oxidized in the oxidation columns throughout the entire study period. Its concentrations were reduced to less than 2.7, 1.2, and 1.0 µg/L following the first and second oxidation and the third adsorption columns, respectively. It appeared that some additional oxidation took place in the three adsorption columns, which also contained $NaIO_4$ as the active oxidizing ingredient (Table 4-2b).

The test results for arsenic removal by the ATS system are shown in Figure 4-10 with total arsenic concentrations plotted against the bed volumes of water treated (BV was calculated based on 1.5 ft^3 or 11.2 gal of media in a column). The results showed that the oxidizing media was effective at not only converting As(III) to As(V), but also removing arsenic. For the first sampling event that occurred 12 days after system startup, the total arsenic concentration in the effluent of the lead oxidation column (i.e., OA) was 2.1 µg/L. Arsenic concentrations slowly increased thereafter to 10 µg/L at about 4,600 BV, and then completely broken through the lead oxidation column at about 7,100 BV.

Arsenic concentrations in the effluent of the lag oxidation column (i.e., OB) remained below 10 µg/L until approximately 8,900 BV (or 4,450 BV if considering the two oxidations columns as one large column) and below influent concentrations until approximately 17,200 BV (or 8,600 BV if considering the two oxidations columns as one large column). There was a concentration drop following both the lead and lag oxidation columns between 10,000 and 15,000 BV. It was not clear what contributed to this concentration drop.

Based on the breakthrough curves shown in Figure 4-10, arsenic loadings on the oxidation media were between 0.18 and 0.20 µg of As/mg of dry media. Table 4-7 summarizes the arsenic mass removed by each oxidation and adsorption columns; detailed calculations of arsenic mass removed are provided in



*Media changeout of the lead and first lag arsenic (TA and TB) adsorption tank occurred on March 14, 2007. The second lag tank (TC) was moved to the lead

Figure 4-10. Arsenic Concentration across Treatment Train (BV Calculations Based upon 1.5 ft^3 of Media in Each Column)

Table 4-7. Arsenic Mass Removed and Loading on Media [(a)]

Column	Arsenic Mass Removed (µg)	Capacity[(b)] (µg of As/mg of dry media)
OA	6,740,472	0.20
OB	5,958,431	0.18
TA	7,522,304	0.23
TB	5,462,514	0.17
TC	4,395,407	0.13[(c)]

(a) More detailed calculations provided in Appendix C.
(b) Based on a bulk density of 51 lb/ft^3 and a moisture content of 5%.
(c) Loading before column shifted to lead position after changeout.

Appendix C. (Note: arsenic loading was calculated by dividing the arsenic mass represented by the shaded area in Figure 4-11 by the dry weight of the media in one column).

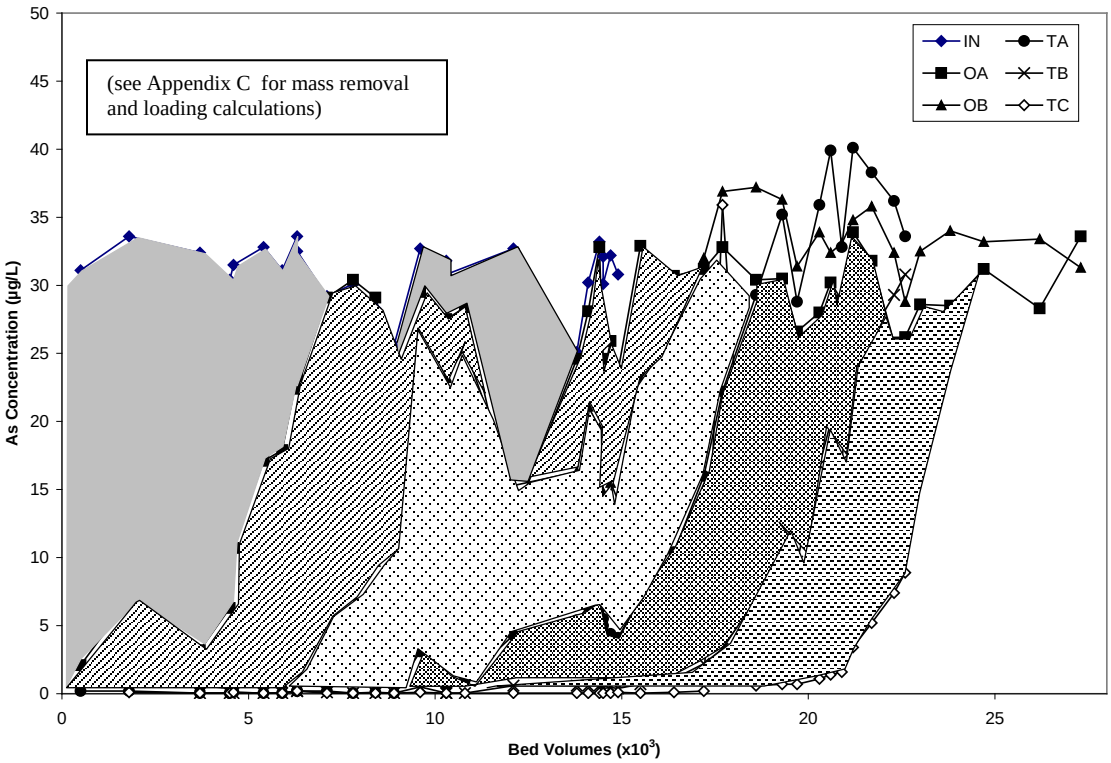


Figure 4-11. Arsenic Mass Removed by Oxidation and Adsorption Columns

Arsenic concentrations after the lead adsorption column (i.e., TA) reached 10 µg/L at approximately 16,400 BV (or 5,470 BV if considering the two oxidation columns and one adsorption column as one large column). Arsenic approached complete breakthrough after the lead column at approximately 20,300 BV (or 6,770 BV if considering the two oxidation columns and one adsorption column as one large column). Arsenic breakthrough from the lead adsorption column occurred much sooner than projected by the vendor (i.e., 42,000 BV). Although within the vendor-provided effective limit of <9.0, the relatively high pH values of source water (averaging 8.4; see Table 4-6) might have contributed, in part, to the early

arsenic breakthrough from the adsorption column. Based on the breakthrough curve shown in Figure 4-10, the arsenic loading on the adsorptive media in the lead column was 0.23 µg of As/mg of dry media, which was very close to that on the oxidizing media. The arsenic mass removed by the lead adsorption column was estimated to be 7.5 g.

Breakthrough curves for the first and second lag columns (i.e., TB and TC) also are presented in Figure 4-10. Arsenic concentrations from the first lag column (i.e., TB) reached 10 µg/L at approximately 19,700 BV (or 4,930 BV if considering the two oxidation columns and two adsorption columns as one large column). Arsenic concentrations from the second lag column (i.e., TC) reached only 8.9 µg/L at the time of media changeout. Because arsenic had not completely broken through the first and second lag columns, the arsenic mass removed by these columns was significantly lower than that by the lead adsorption column.

The 0.23 µg of As/mg of dry media adsorptive capacity observed at Susanville, CA is comparable to that of the same media (i.e., 0.18 to 0.29 µg of As/mg of dry media [Table 4-8]) evaluated at another arsenic removal technology demonstration site at Wales, ME (Lipps et al., 2006, 2009a). The Wales system has two identical treatment trains, each consisting of one oxidation column and three adsorption columns configured for series operations similar to the Susanville system. At Susanville, CA, arsenic broke

Table 4-8. Comparison of Media Run Length and Arsenic Loading at Three Arsenic Demonstration Sites Using ATS' Media

Column	Run Length to 10 µg/L (BV)	Run Length to Capacity (BV)	Arsenic Loading on Media at Capacity (µg/mg)	Average Treatment Train Flowrate (gpm)	Average Influent Total Arsenic Concentration (µg/L)	Average Influent pH (S.U.)	Average Influent Silica Concentration (mg/L)
Susanville							
OA	4,600	7,100	0.20	9.3	31.7	8.4	14.1
OB	4,450	8,600	0.18				
TA	5,470	6,670	0.23				
TB	4,930	NA	NA				
TC	NA	NA	NA				
Dummerston[(a)]							
TA	5,700	12,000	0.50	<3.6 (Train A); <4.0 (Train B)	42.2	7.7	12.6
TB	5,400	12,000	0.46				
TC	6,500	NA	NA				
TD	6,250	NA	NA				
TE	NA	NA	NA				
TF	NA	NA	NA				
Wales[(b)]							
OA	2,400/2,700	4,600/4,700	0.14/0.16	4.7 (Train A); 4.9 (Train B)	39.1	8.5	10.5
OB	1,200/2,800	5,100/5,100	0.10/0.18				
TA	3,550/3,350	4,900/4,800	0.23/0.19				
TB	2,950/3,750	4,450/6,100	0.19/0.27				
TC	3,575/3,775	4,100/4,750	0.18/0.26				
TD	3,500/3,800	4,325/4,825	0.28/0.21				
TE	3,825/3,800	4,750/NA	0.26/0.22[(c)]				
TF	3,775/3,950	4,625/NA	0.28/0.22[(c)]				

(a) Lipps et al., 2006 and 2009.
(b) Lipps et al., 2006 and 2009.
(c) Column had not reached capacity.

through at 10 µg/L from each adsorption column after treating 4,930 to 5,470 BV of water, which were somewhat higher than those observed for the Wales system (i.e., from 2,950 to 3,975 BV), even though the Wales system had a much lower flowrate (i.e., 5.1 to 5.2 gpm vs. 9.3 gpm per treatment train). At Susanville, CA, complete breakthrough occurred at 6,670 BV, which also was somewhat higher than that (i.e., from 4,150 to 6,100 BV) observed at Wales, ME. The Wales source water had a pH value comparable to that of Susanville (i.e., 8.5 vs. 8.4), but it had higher arsenic and lower silica concentrations.

A/P Complex 2002 oxidizing media had an adsorptive capacity comparable to that of A/I Complex 2000 adsorptive media (i.e., 0.18 to 0.20 vs. 0.23 µg of As/mg of dry media), although this adsorptive capacity was somewhat higher than those (i.e., 0.1 to 0.19 µg of As/mg of dry media) observed at Wales, ME.

The adsorptive capacities of A/I Complex 2000 adsorptive media observed at Susanville, CA and Wales, ME were about half of those (i.e., 0.46 to 0.50 µg of As/mg of dry media [Table 4-8]) observed for the third ATS system at Dummerston, VT. The Dummerston system consists of only three adsorption columns due to the presence of only soluble As(V) in that source water (Lipps et al., 2007, 2009b). As expected, arsenic breakthrough at 10 µg/L and at capacity from the Dummerston system occurred after treating more water at 5,400–6,500 BV and 12,000 BV, respectively. The higher adsorptive capacity and longer media run length observed at Dummerston were believed to have been caused by the lower pH value of the source water, which averaged at 7.7 (compared to 8.4 and 8.5 at Susanville and Wales, respectively). The Dummerston system also had the lowest flowrate at <4.0 gpm per treatment train.

Relatively short run length seemed to be the common result observed for all three ATS systems using A/I Complex 2000 adsorptive media. The longest was 6,500 BV and the shortest was 2,950 BV. Among others, pH of source water appeared to be the main factor affecting the media run length.

4.5.1.2 Silica, Sulfate, Bicarbonate and Nitrate. Among the anions analyzed, silica, sulfate, alkalinity (existing primarily as HCO_3^- at pH values between 7.4 and 8.8), and nitrate were present in significant concentrations in raw water (Table 4-6) and some potentially could compete with arsenic for adsorptive sites. As shown in Figure 4-12, silica was consistently removed by, and did not reach complete breakthrough from either the adsorption or the oxidation columns. However, HCO_3^-, SO_4^{2-}, and NO_3^- showed little to no adsorptive capacity on the media (Figure 4-13).

4.5.1.3 Aluminum. As shown in Table 4-5, total aluminum concentrations in source water were below detection. Aluminum concentrations (existing primarily in soluble form) in the treated water following the oxidation and adsorption columns were about 14 to 40 µg/L, which were higher than those in raw water, indicating leaching of aluminum from the oxidizing and adsorptive media. With the increase in aluminum concentrations following the treatment system, the concentrations, however, were below the EPA secondary drinking water standard for aluminum of 50 to 200 µg/L and the California primary MCL of 1 mg/L. Leaching of aluminum continued throughout the study period (Figure 4-14).

4.5.1.4 Iron and Manganese. Iron concentrations, both total and dissolved, were <25 to 136 µg/L in source water and below the method reporting limit across the treatment train (Table 4-5). Manganese concentrations in source water also were low, ranging from 3.5 to 7.7 µg/L and averaging 5.4 µg/L. Manganese concentrations in the treated water following the adsorption columns were typically below the method reporting limit of 1 µg/L, indicating complete removal of manganese by the oxidizing and adsorptive media.

4.5.1.5 Other Water Quality Parameters. Fluoride, orthophosphate, total phosphorus, and hardness concentrations remained relatively constant throughout the treatment train.

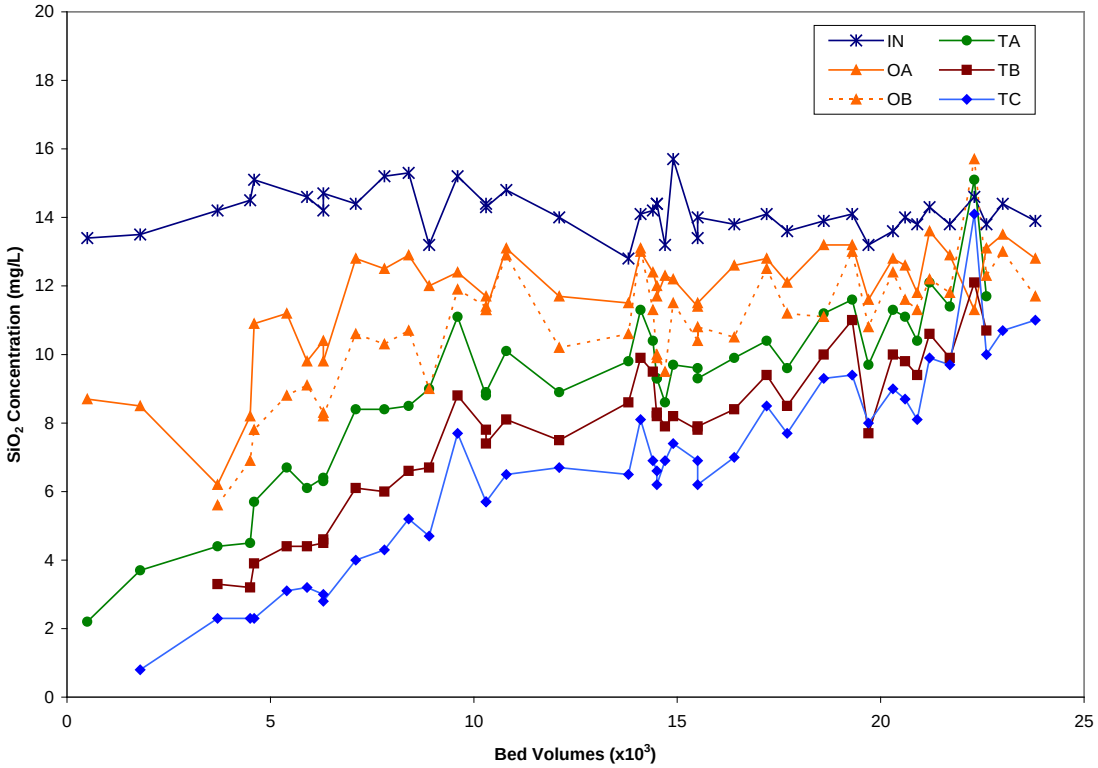


Figure 4-12. Silica Concentrations across Treatment Train (BV Calculations Based upon 1.5 ft^3 of Media in Each Column)

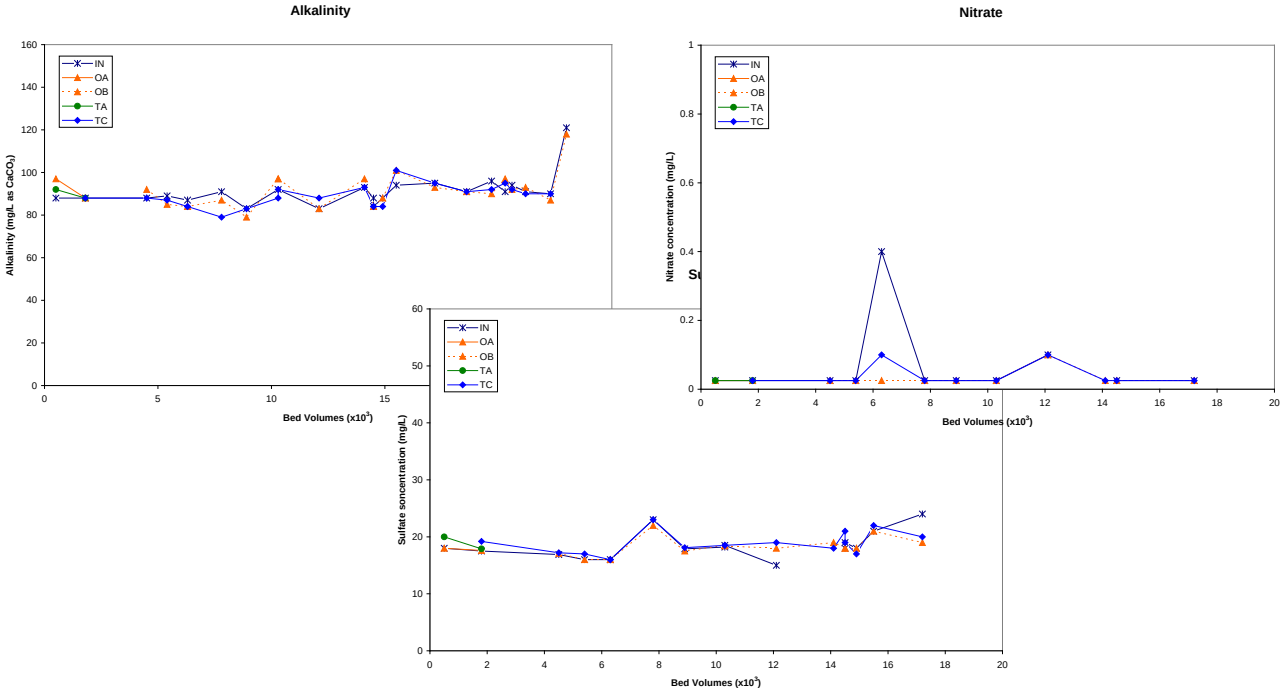


Figure 4-13. Alkalinity, Sulfate and Nitrate Concentrations across Treatment Train (BV Calculations Based upon 1.5 ft^3 of Media in Each Column)

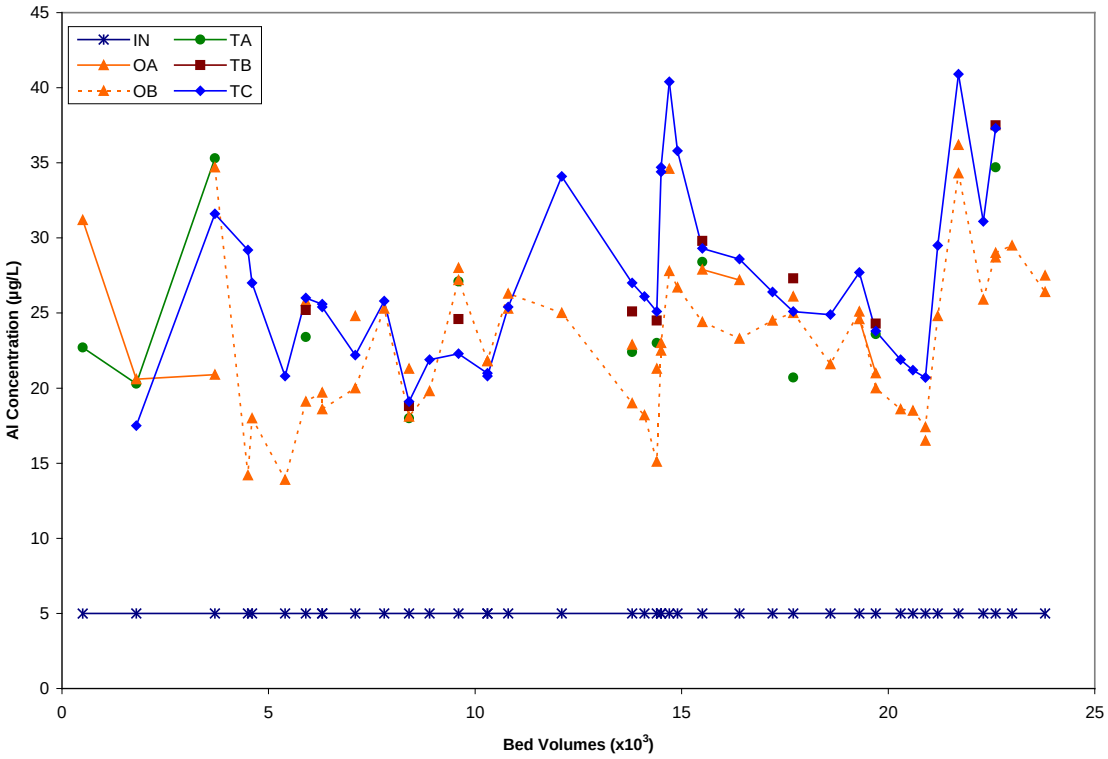


Figure 4-14. Aluminum Concentrations across Treatment Train (BV Calculations Based upon 1.5 ft^3 of Media in Each Column)

4.5.2 Spent Media Sampling. Spent media samples were collected from Adsorption Columns A and B after media changeout on March 14, 2007. The oxidation columns continued to be effective in oxidizing As(III) to As(V) and, therefore, were not replaced and no spent oxidizing media samples were collected. The samples were collected according to Section 3.3.3 for TCLP and total metals analysis and the analytical results are presented in Tables 4-9 and 4-10, respectively.

Table 4-9. TCLP Results of Spent Media from Columns A and B

Analyte	Concentration (mg/L)
Arsenic	<0.10
Barium	0.5
Cadmium	<0.010
Chromium	<0.010
Lead	<0.050
Mercury	<0.0020
Selenium	<0.10
Silver	<0.010

4.5.2.1 TCLP. The TCLP results indicated that the spent media was non-hazardous and could be disposed of in a sanitary landfill. Barium was the only metal detected by the TCLP test at a concentration of 0.5 mg/L, which is well below its limit of 100 mg/L.

Table 4-10. Spent Media Metals Results of Duplicate Samples

Sampling Date		03/14/07	
Sampling Location		TA	TB
Parameter	Unit		
Bed Volume	BV^3	22.9	22.9
Aluminum	µg/g	375,672	373,585
		384,433	378,184
Arsenic	µg/g	215	226
		220	230
Cadmium	µg/g	<0.53	<0.53
		<0.53	<0.53
Calcium	µg/g	7,717	7,568
		7,709	6,797
Copper	µg/g	2.02	1.63
		1.91	2.15
Iodine	µg/g	185	-
		157	-
Iron	µg/g	9,949	10,739
		10,593	10,295
Lead	µg/g	<0.53	<0.53
		<0.53	<0.53
Magnesium	µg/g	938	862
		975	872
Manganese	µg/g	54.4	55.6
		55.1	52.7
Nickel	µg/g	1.00	0.88
		1.07	0.95
Phosphorus	µg/g	164	164
		179	120
Silica	µg/g	<267	467
		303	<269
Zinc	µg/g	<53.4	<53.7
		<53.1	<53.8

4.5.2.2 Metals. The ICP-MS results indicated that both the lead and the first lag columns (TA and TB) had reached their capacities for arsenic, as evident by the nearly identical loadings, i.e., 0.22 and 0.23 µg/mg of dry media on both columns. These values also were very close to that estimated via the arsenic breakthrough curve for Column A, as shown in Table 4-11. For Column B, the breakthrough curve result was 26% lower. The A/I Complex 2000 dry media mass was calculated based on a moisture content of 8%, as measured in the laboratory, for the ICP-MS results and 5%, based on vendor's literature for the "as-is" media, for the results from the breakthrough curves.

Except for aluminum, iron, and calcium, all metals analyzed on the spent media were at trace levels. The average aluminum composition was 38%, equivalent to 72% of Al_2O_3, which was significantly lower than the 91% specified by ATS (Table 4-2b). The average iron composition was 1%, equivalent to 7% of $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$, which was very close to the specified value of 5.9%. Calcium measured was 0.72%. Iodine composition was 0.02%, equivalent to 0.03% $NaIO_4$, which was significantly lower than the 3.21% specified by ATS (Table 4-2b). A small amount of $NaIO_4$ might have been consumed to oxidize any reducing species remaining in the oxidation column effluent; some also was leached into the treated water as shown in Figure 4-9.

Table 4-11. Comparison of Media Capacity for Arsenic

Column	Estimated via Breakthrough Curves[a] (Figure 4-11)	Estimated via Spent Media ICP-MS Results[b] (Table 4-10)
	(µg of As/mg of dry media)	
TA	0.23	0.22
TB	0.17	0.23

(a) Calculations account for 5% moisture content of A/I Complex 2000 media.
(b) Averages of duplicate analyses.

4.5.3 Distribution System Water Sampling. Prior to the installation/operation of the treatment system, baseline distribution system water samples were collected from three LCR taps on July 21, 2005, August 4, 2005, and August 24, 2005. Following treatment startup, distribution water sampling continued on a monthly basis at the same three locations for one year. The results of the distribution system sampling are summarized in Table 4-12. As expected, prior to the installation of the arsenic adsorption system, arsenic concentrations in the distribution system were similar to those measured in raw water, ranging from 11.6 to 43.3 µg/L, averaging 30.6 µg/L. After system startup, arsenic concentrations in the distribution system were significantly reduced to less than 4.9 µg/L (or 1.5 µg/L on average), which, although low, were still higher than the concentrations (≤0.2 µg/L) measured at the distribution entry point. Therefore, some dissolution and/or resuspension of arsenic might have occurred in the distribution system. Arsenic concentrations remained below 5 µg/L at all three sampling locations throughout the one-year monitoring of the distribution system water quality.

Similar to those in raw water, iron and manganese concentrations were low in the distribution system. Lead and copper values also were low and did not appear to have been affected by the treatment system. The pH and alkalinity values remained fairly constant throughout the distribution system.

4.6 System Cost

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. This included the tracking of the capital cost for the treatment system such as equipment, site engineering, and installation and the O&M cost for electrical power usage and labor. No cost was incurred for building and discharge-related infrastructure improvements. If required, this cost would have been funded by the demonstration site and, therefore, not included in the following cost analyses.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation was $16,930 (see Table 4-13). The equipment cost was $8,640 (or 51% of the total capital investment), which included $2,170 for the treatment system mechanical hardware, $960 for 3 ft^3 of the A/P Complex 2002 oxidizing media (i.e., $320/$ft^3$ or $6.27/lb), $1,440 for 9 ft^3 of the A/I Complex 2000 adsorptive media (i.e., $320/$ft^3$ or $6.27/lb), $1,950 for the pressure tank and booster pump, and $2,120 for vendor's labor and freight.

The engineering cost included the cost for the preparation of the system layout and footprint, design of the piping connections to the entry and distribution tie-in points, and assembling and submission of the engineering plans for the permit application (Section 4.3). The engineering cost was $3,400, or 20% of the total capital investment.

Table 4-12. Distribution System Sampling Results

Sampling Event		DS1								DS2								DS3							
		Hall Sink								Kitchen Sink								Office Room Sink							
		LCR								LCR								LCR							
		1st draw								1st draw								1st Draw							
		Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu
No.	Date	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	07/21/05	>12[a]	8.0	88	31.2	<25	4.3	4.6	13.6	17.8	8.0	88	27.5	<25	4.8	1.0	4.5	17.8	8.0	88	35.1	32.4	5.0	10.4	7.0
BL2	08/04/05	>12[a]	8.0	87	36.6	<25	5.4	1.8	8.7	>12[a]	8.1	86	23.5	<25	4.4	0.8	2.9	>12[a]	8.1	77	31.2	<25	5.5	2.4	5.9
BL3	08/24/05	>12[a]	8.0	88	35.4	<25	4.9	3.8	27.2	>12[a]	8.1	88	43.3	<25	4.7	3.2	69.4	>12[a]	7.3	88	11.6	45.1	25.1	6.6	83.9
1	10/17/05	>12[a]	7.0	88	1.2	<25	1.6	1.9	4.5	>12[a]	7.1	88	1.1	<25	1.7	0.5	1.5	>12[a]	7.3	88	1.1	<25	6.1	1.5	27.3
2	11/21/05	>12[a]	7.5	88	1.4	<25	1.4	0.4	12.9	>12[a]	7.7	83	1.1	<25	0.8	0.9	6.8	>12[a]	7.9	83	1.4	<25	3.9	3.6	14.6
3	12/07/05	>12[a]	7.7	83	0.8	<25	0.6	0.3	1.8	>12[a]	7.7	83	0.9	<25	2.2	0.3	1.9	>12[a]	7.7	81	1.3	<25	3.1	5.4	17.5
4	01/19/06	>12[a]	7.6	85	1.0	<25	0.7	1.9	9.1	>12[a]	7.6	86	0.8	<25	1.6	0.6	2.9	>12[a]	7.6	86	1.4	32.8	2.7	5.9	31.5
5	02/16/06	>12[a]	7.8	87	0.8	<25	0.6	0.3	1.6	>12[a]	7.8	83	0.7	<25	0.3	<0.1	1.5	>12[a]	7.8	83	1.1	<25	0.6	0.7	6.4
6	03/15/06	10.0	7.6	83	0.3	<25	0.1	0.6	8.7	9.9	7.8	83	0.3	<25	1.7	0.7	2.5	9.9	7.7	83	0.8	<25	0.4	1.9	38.7
7	04/11/06	19.0	7.8	88	1.6	36.5	0.6	0.7	9.9	7.5	7.8	88	1.8	<25	2.6	0.8	7.1	15.3	7.8	88	2.4	67.8	1.1	3.5	21.9
8	05/10/06	11.2	8.0	88	1.3	<25	0.4	<0.1	1.5	12.0	8.0	85	1.4	<25	0.6	<0.1	3.1	11.1	8.0	192	3.2	27.1	1.1	5.1	11.0
9	06/07/06	13.9	7.9	89	1.2	<25	0.2	0.1	2.6	10.8	7.9	86	1.1	<25	1.1	0.2	5.7	10.8	7.8	88	2.8	<25	0.8	4.5	10.8
10	07/19/06	10.0	7.8	92	1.2	<25	0.6	3.6	16.9	10.4	7.8	92	1.3	<25	1.6	1.9	12.2	11.0	7.9	97	4.6	211	3.0	10.6	24.2
11	08/16/06	>12[a]	7.8	86	1.3	<25	0.5	1.1	15.1	>12[a]	7.8	87	1.2	<25	0.4	0.6	9.3	>12[a]	7.7	90	4.9	39.6	2.0	3.4	29.1
12	09/12/06	>12[a]	7.7	88	0.5	<25	<0.1	2.0	15.5	13.3	7.6	88	2.9	28	1.4	6.8	14.8	13.3	7.7	86	0.7	<25	1.2	0.5	8.4

BL = Baseline sampling; NS = not sampled; NA = data not available.
Lead action level = 15 µg/L; copper action level = 1.3 mg/L.
(a) Exact stagnation time unknown

Table 4-13. Summary of Capital Investment Cost

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Cost			
Oxidation Columns (Without Media)	2	$240	–
A/P Complex 2002 Oxidizing Media (ft^3)	3	$960	–
Adsorption Columns (Without Media)	3	$360	–
A/I Complex 2000 Adsorptive Media (ft^3)	4.5	$1,440	–
25-µm Sediment Filter	1	$350	–
Piping and Valves	1	$510	–
Flow Totalizer/Meter	1	$560	–
Hour Meter	1	$150	
Pressure Tank/Booster Pump	1	$1,950	
Procurement, Assembly, Labor	1	$1,000	–
Freight	1	$1,120	–
Equipment Total	–	**$8,640**	**51%**
Engineering Cost			
Design/Scope of System (hr)	10	$1,500	–
Travel and Miscellaneous Expenses	1	$1,400	–
Subcontractor Labor	–	$500	
Engineering Total	–	**$3,400**	**20%**
Installation Cost			
Plumbing Supplies/Parts	1	$300	–
Vendor Installation Labor (hr)	10	$1,300	–
Subcontractor Labor (hr)	6	$390	
Vendor Travel (day)	2	$2,800	–
Subcontractor Travel	–	$100	–
Installation Total	–	**$4,890**	**29%**
Total Capital Investment	–	**$16,930**	**100%**

The installation cost included the cost to unload and install the treatment system, pressure tank, and booster pump, complete the piping installation and tie-ins, and perform system start-up and shakedown (Section 4.3). The installation cost was $4,890, or 29% of the total capital investment.

Using the system's rated capacity of 12 gpm (or 17,280 gpd), the capital cost was $1,410/gpm (or $0.98/gpd). The capital cost of $16,930 was converted to an annualized cost of $1,598/yr using a capital recovery factor of 0.09439 based on a 7% interest rate and a 20-yr return. Assuming that the system was operated 24 hr a day, 7 days a week at the design flow rate of 12 gpm to produce 6,300,000 gal of water per year, the unit capital cost would be $0.25/1,000 gal. However, since the system produced 180,520 gal of water during the first year of system operations, the unit capital cost was increased to $8.90/1,000 gal at this reduced rate of production.

4.6.2 Operation and Maintenance Cost. The O&M cost for the As/1200CS treatment system included only incremental cost associated with the adsorption system, such as media replacement and disposal, electricity, and labor (Table 4-14). For a three-column system operating in series, the media in the lead column is ideally replaced when the arsenic concentration in the lead column effluent equals the raw water concentration but before the concentration following the final lag column reaches the 10 µg/L target value. Once the lead column is exhausted, the first and second lag columns are moved up to the lead and first lag positions and a column containing new media is placed in the final lag position. The method allows the media's capacity for arsenic to be fully utilized before its replacement. If the media

has a sharp adsorption front (with a typical S-shaped breakthrough curve) and the anticipated run length is relatively short; however, it may be more cost-effective to replace the first two or all three columns in the treatment train when required.

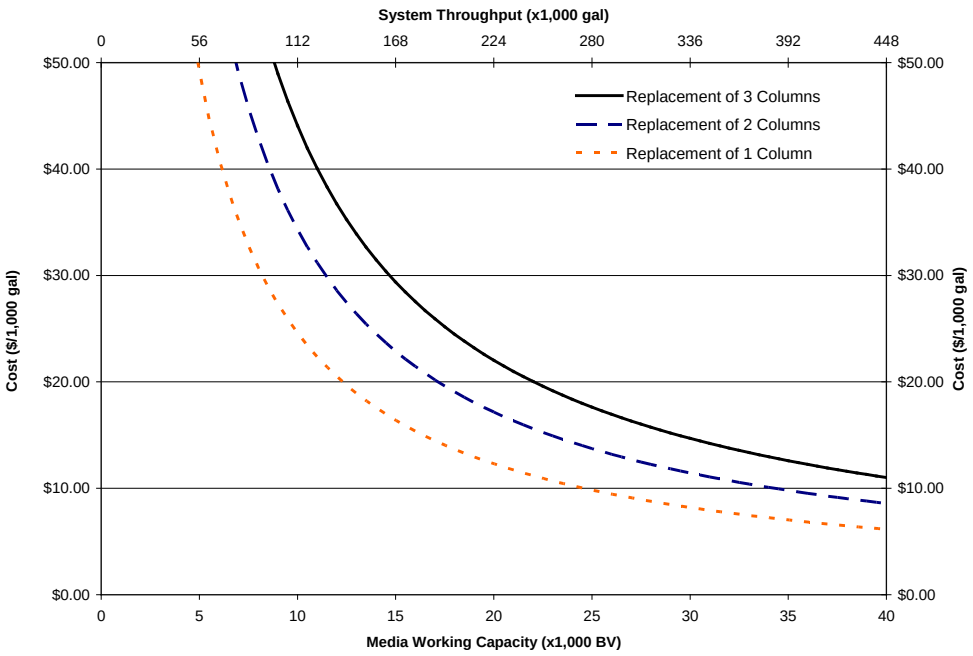
Table 4-14. Summary of O&M Cost

Cost Category	Value			Assumptions
Volume Processed (1,000 gal)	254			From 09/07/5 through 03/09/07
Media Replacement and Disposal				
Number of Columns Replaced	1	2	3	
Media Replacement and Disposal ($)	675	1,350	2,025	$675/column or $450/ft^3 of media
Sediment filter and tank accessories	115	115	115	
Shipping ($)	423	845	1,268	
Labor and Travel ($)	0 (1,660)	0 (1,660)	0 (1,660)	Because operator conducted changeout, no labor and travel charged (quote for vendor to conduct changeout)
Subtotal ($)	1,213	2,310	3,408	–
Media Replacement and Disposal Cost ($/1,000 gal)	See Figure 4-15			–
Electricity Consumption				
Electricity Cost ($/1,000 gal)	0.001			Electrical cost negligible
Labor				
Average Weekly Labor (hr)	0.33			20 min/wk
Labor Cost ($)	782			0.33 hr/wk × 79 wk × $30/hr labor rate
Labor Cost ($/1,000 gal)	3.10			–
Total O&M Cost ($/1,000 gal)	Adsorptive media replacement + oxidizing media replacement + 3.10			

At Susanville, the lead and first lag columns were changed out on March 14, 2007 after approximately 18 months of system operation. The cost of the changeout for two columns (lead and first lag) was $2,310 (see cost breakdown in Table 4-14). The spent media was returned to ATS and sold for use in another product; therefore, there was no additional cost for disposal of spent media. Using this $2,310 quote, the cost of changing out one and three columns was estimated to be $1,213 and $3,408, respectively. By averaging the media replacement cost over the life of the media, the cost per 1,000 gal of water treated by replacing one, two, and three columns at a time was plotted as a function of the media run length in BV in Figure 4-14. To be consistent with the operational data, the media run length in BV was calculated by dividing the system throughput by the quantity of media in one column, i.e., 1.5 ft^3 (or 11.2 gal).

Additional electricity use associated with the hour meters on the booster pump and well pump and a new booster pump following the treatment system was minimal. The routine, non-demonstration-related labor activities consumed about 20 min/wk as noted in Section 4.4.3. Therefore, the estimated labor cost was $3.10/1,000 gal of water treated (Table 4-14).

As shown in Table 4-14, the unit O&M cost is driven by the cost to replace the spent media and is a function of the media run length (see Figure 4-15). The electricity cost is minimal. The labor cost is based on only 20 min/wk of labor to provide a minimum amount of system O&M. Depending on how consistently the system performs and if any additional troubleshooting is required, the labor cost could increase significantly after the demonstration study.



Note: 1 BV = 1.5 cubic feet = 11.2 gal

Figure 4-15. Media Replacement Cost Curves for As/1200CS System

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APPENDIX A

OPERATIONAL DATA

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

			Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
											Booster Pump/ System	Well Pump						
Week No.	Date	Time	Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Average (Instanteous) Flowrate	Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
1	09/08/05	07:00	0.0	0.0	0.0	0.0	-	0	-	-	-	-	50	-	-	-	-	-
	09/09/05	10:55	0.5	0.5	1.4	1.4	643	643	57	57	7.7 (-)	21.4	41	38	32	27	18	13
2	09/12/05	15:45	1.1	1.6	3.1	4.4	1,238	1,881	110	168	6.8 (-)	18.8	53	-	-	-	-	-
	09/13/05	10:28	0.3	1.9	0.8	5.3	279	2,159	25	192	5.8 (-)	15.5	42	39	33	28	19	15
	09/14/05	11:00	0.7	2.6	1.9	7.2	717	2,876	64	256	6.3 (-)	17.1	55	-	-	-	-	-
	09/16/05	07:06	1.3	3.9	3.6	10.8	1,615	4,491	144	400	7.5 (-)	20.7	37	42	42	42	40	42
3	09/19/05	07:15	1.0	4.9	2.8	13.6	976	5,466	87	487	5.9 (-)	16.3	35	33	27	22	15	11
	09/20/05	07:10	1.1	6.0	3.1	16.6	1,390	6,856	124	611	7.5 (-)	21.1	36	42	42	42	40	42
7	10/17/05	10:25	11.1	17.1	30.7	47.4	13,669	20,525	1,218	1,829	7.4 (-)	20.5	38	35	29	24	15	10
9	11/01/05	13:06	-	-	-	-	20,360	40,885	1,815	3,644	NM	NM	40	38	32	25	16	12
	11/02/05	10:07	7.1	24.2	19.7	67.0	360	41,245	32	3,676	17.6 (-)	48.6	41	38	32	26	16	11
12	11/21/05	14:15	-	-	-	-	9,313	50,558	830	4,506	NM	NM	NM	NM	NM	NM	NM	NM
13	11/29/05	14:20	7.9	32.1	21.9	88.9	1,029	51,587	92	4,598	7.9 (-)	21.8	37	35	30	26	18	16
	11/30/05	12:56	0.5	32.6	1.4	90.3	596	52,183	53	4,651	7.1 (-)	19.9	44	41	36	30	22	18
	12/04/05	12:15	1.5	34.1	4.2	94.5	1,938	54,121	173	4,824	7.7 (-)	21.5	48	45	38	31	21	15
14	12/05/05	14:45	0.3	34.4	0.8	95.3	439	54,560	39	4,863	9.1 (-)	24.4	47	44	37	31	21	16
	12/08/05	10:15	1.5	35.9	4.2	99.4	1,971	56,531	176	5,038	7.8 (-)	21.9	43	41	35	31	22	17
	12/09/05	10:30	0.8	36.7	2.2	101.7	1,107	57,638	99	5,137	8.4 (-)	23.1	45	41	36	31	22	19
15	12/12/05	14:04	1.6	38.3	4.4	106.1	2,145	59,783	191	5,328	8.1 (8.1)	22.3	36	35	29	24	15	11
	12/13/05	12:25	0.3	38.6	1.0	107.0	524	60,307	47	5,375	8.7 (7.1)	29.1	38	35	29	23	15	10
	12/14/05	09:30	0.3	38.9	0.7	107.7	367	60,674	33	5,408	8.7 (7.7)	20.4	36	33	27	22	15	11

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

Week No.	Date	Time	Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
			Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Booster Pump/ System Average (Instanteous) Flowrate	Well Pump Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
18	01/05/06	08:00	3.6	42.5	9.9	117.6	5,115	65,789	456	5,864	8.6 (8.7)	23.7	40	36	31	26	16	11
	01/06/06	13:10	0.7	43.2	1.7	119.3	876	66,665	78	5,942	8.6 (8.7)	20.9	42	38	31	26	16	12
19	01/09/06	10:30	0.2	43.4	0.7	120.0	370	67,035	33	5,975	8.8 (9.3)	30.8	46	44	36	30	20	16
	01/10/06	10:00	0.5	43.9	1.3	121.3	678	67,713	60	6,035	8.7 (8.5)	22.6	40	36	31	26	16	11
	01/11/06	10:25	0.6	44.5	1.7	123.0	859	68,572	77	6,112	8.4 (8.6)	23.9	44	40	35	29	20	16
	01/12/06	11:01	0.7	45.2	1.9	124.9	975	69,547	87	6,198	8.6 (9.3)	23.2	47	44	38	31	21	16
	01/13/06	14:35	0.6	45.8	1.8	126.7	929	70,476	83	6,281	8.6 (8.7)	26.8	42	40	34	27	18	12
20	01/17/06	10:45	0.2	46.0	0.5	127.2	276	70,752	25	6,306	9.2 (8.1)	23.0	42	39	33	27	18	12
	01/18/06	09:05	0.5	46.5	1.4	128.6	717	71,469	64	6,370	8.5 (8.3)	23.9	41	39	33	27	18	13
	01/19/06	09:40	0.7	47.2	1.9	130.5	1,007	72,476	90	6,460	8.8 (7.6)	22.8	31	29	23	19	10	8
	01/20/06	13:40	0.9	48.1	2.0	132.5	1,016	73,492	91	6,550	8.5 (9.5)	18.8	49	47	39	33	21	16
21	01/23/06	12:00	0.4	48.5	1.0	133.5	510	74,002	45	6,596	8.5 (9.8)	21.3	53	50	42	35	24	18
	01/26/06	11:31	1.2	49.7	3.6	137.1	1,854	75,856	165	6,761	8.6 (7.7)	25.8	36	34	28	22	14	10
22	01/30/06	14:30	1.2	50.9	3.3	140.4	1,746	77,602	156	6,916	8.8 (8.9)	24.3	54	51	43	36	25	18
	02/01/06	11:00	0.6	51.5	1.7	142.1	908	78,510	81	6,997	8.9 (8.5)	25.2	40	37	31	26	16	11
	02/02/06	12:00	0.7	52.2	1.8	143.9	934	79,444	83	7,081	8.6 (9.3)	24.2	46	44	38	31	21	16
	02/03/06	10:00	0.5	52.7	1.7	145.6	916	80,360	82	7,162	9.0 (7.9)	30.5	36	34	27	21	14	8
23	02/06/06	11:30	2.1	54.8	4.9	150.5	2,528	82,888	225	7,388	8.6 (9.6)	22.4	55	52	44	36	24	19
	02/07/06	14:30	0.8	55.6	2.4	152.9	1,265	84,153	113	7,500	8.8 (8.8)	26.4	43	41	34	28	18	12
	02/08/06	12:00	0.6	56.2	0.8	153.7	443	84,596	39	7,540	9.2 (9.8)	12.3	49	47	40	33	22	17
	02/09/06	11:00	0.2	56.4	1.5	155.2	738	85,334	66	7,606	8.2 (9.6)	61.5	54	51	44	36	25	18

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

Week No.	Date	Time	Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
			Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Booster Pump/ System Average (Instanteous) Flowrate	Well Pump Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
24	02/14/06	10:15	0.6	57.0	1.6	156.8	897	86,231	80	7,685	9.3 (8.4)	24.9	42	39	33	26	17	12
	02/15/06	15:00	0.7	57.7	2.0	158.8	970	87,201	86	7,772	8.1 (9.7)	23.1	50	48	40	34	22	16
	02/16/06	14:00	0.2	57.9	0.5	159.3	264	87,465	24	7,795	8.8 (9.1)	22.0	44	42	34	28	18	12
	02/17/06	13:00	0.7	58.6	2.0	161.3	1,095	88,560	98	7,893	9.1 (8.4)	26.1	43	40	33	27	17	12
25	02/22/06	12:00	0.7	59.3	2.2	163.5	1,113	89,673	99	7,992	8.4 (8.0)	26.5	36	35	29	22	9	9
	02/24/06	11:05	0.9	60.2	2.5	166.0	1,324	90,997	118	8,110	8.8 (7.5)	24.5	37	24	29	23	11	11
26	02/27/06	12:00	0.8	61.0	2.0	168.0	1,042	92,039	93	8,203	8.7 (8.6)	21.7	54	51	44	36	25	18
	02/28/06	13:00	0.4	61.4	1.3	169.3	690	92,729	61	8,265	8.8 (9.7)	28.8	53	50	44	36	24	18
	03/01/06	12:00	0.3	61.7	0.8	170.1	443	93,172	39	8,304	9.2 (8.9)	24.6	42	39	31	26	16	11
	03/02/06	09:20	0.4	62.1	1.1	171.2	555	93,727	49	8,354	8.4 (8.4)	23.1	40	37	30	24	15	11
27	03/06/06	14:00	1.3	63.4	3.6	174.8	1,912	95,639	170	8,524	8.9 (9.9)	24.5	50	47	40	33	21	16
	03/07/06	07:20	0.2	63.6	0.4	175.2	211	95,850	19	8,543	8.8 (9.3)	17.6	52	48	41	34	23	18
	03/09/06	08:15	1.0	64.6	2.9	178.1	1,525	97,375	136	8,679	8.8 (9.3)	25.4	40	37	32	26	17	14
	03/10/06	13:10	0.7	65.3	2.1	180.2	1,095	98,470	98	8,776	8.7 (-)	26.1	54	51	44	36	25	18
28	03/14/06	15:00	1.5	66.8	3.0	183.2	1,528	99,998	136	8,911	8.5 (8.6)	17.0	42	40	33	26	17	12
	03/15/06	15:00	0.1	66.9	0.3	183.5	143	100,141	13	8,925	7.9 (8.4)	23.8	40	37	31	26	16	12
	03/17/06	15:00	0.7	67.6	3.5	187.0	1,855	101,996	165	9,090	8.8 (8.2)	44.2	39	35	30	25	15	11
29	03/20/06	14:15	0.4	68.0	1.0	188.0	543	102,539	48	9,138	9.1 (9.2)	22.6	49	47	39	38	21	16
	03/22/06	7:00	0.9	68.9	2.6	190.6	1,321	103,860	118	9,256	8.5 (8.2)	24.5	39	36	30	24	16	10
	03/24/06	6:30	1.0	69.9	2.8	193.4	1,466	105,326	131	9,387	8.7 (8.5)	24.4	49	46	39	32	21	16

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

Week No.	Date	Time	Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
			Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Booster Pump/ System Average (Instanteous) Flowrate	Well Pump Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
30	03/27/06	11:59	0.6	70.5	2.0	195.4	1,046	106,372	93	9,480	8.7 (9.7)	24.9	51	49	42	35	24	19
	03/28/06	13:30	0.7	71.2	1.7	197.1	903	107,275	80	9,560	8.9 (9.7)	21.5	50	47	40	33	22	16
	03/29/06	10:40	0.3	71.5	0.9	198.0	491	107,766	44	9,604	9.1 (8.4)	27.3	40	36	30	25	16	10
	03/30/06	10:15	1.4	72.9	2.4	200.4	1,236	109,002	110	9,714	8.6 (8.1)	14.7	40	36	30	26	16	11
31	04/03/06	14:00	1.4	74.3	4.1	204.5	2,149	111,151	192	9,906	8.7 (8.5)	25.6	41	37	31	26	16	11
	04/06/06	15:00	1.5	75.8	4.1	208.6	2,160	113,311	193	10,099	8.8 (9.4)	24.0	47	44	39	31	21	16
32	04/11/06	9:00	1.4	77.2	3.2	211.8	1,693	115,004	151	10,250	8.8 (-)	20.2	51	49	41	36	22	16
33	04/17/06	10:45	0.2	77.4	0.7	212.5	343	115,347	31	10,281	8.2 (8.5)	28.6	54	51	46	40	31	24
	04/19/06	10:30	0.9	78.3	2.6	215.1	1,341	116,688	120	10,401	8.6 (8.6)	24.8	43	41	35	31	22	20
	04/20/06	10:15	1.0	79.3	2.8	217.9	1,500	118,188	134	10,535	8.9 (8.3)	25.0	38	35	29	24	14	11
34	04/25/06	11:30	1.0	80.3	3.0	220.9	1,572	119,760	140	10,675	8.7 (8.0)	26.2	46	43	36	30	21	16
	04/26/06	14:00	0.6	80.9	2.0	222.9	1,057	120,817	94	10,769	8.8 (7.6)	29.4	36	34	28	22	14	9
	04/28/06	14:00	0.7	81.6	2.6	225.5	1,363	122,180	101	10,890	8.7 (8.9)	32.5	49	46	39	32	21	16
35	05/01/06	9:45	0.3	81.9	1.0	226.5	505	122,685	45	10,935	8.4 (8.2)	28.1	42	39	33	26	16	11
	05/03/06	8:00	1.6	83.5	22.6	249.1	12,947	135,632	1,154	12,089	9.5 (9.8)	134.9	43	38	27	29	19	16
36	05/08/06	7:45	1.9	85.4	9.7	258.8	5,230	140,862	466	12,555	9.0 (8.1)	45.9	39	36	30	24	16	10
	05/10/06	9:15	1.9	87.3	5.5	264.3	2,788	143,650	248	12,803	8.4 (8.4)	24.5	41	37	31	25	16	11
37	05/16/06	8:20	1.9	89.2	5.2	269.5	2,669	146,319	238	13,041	8.6 (8.7)	23.4	42	38	32	26	16	11
	05/18/06	14:00	3.1	92.3	3.8	273.3	2,040	148,359	182	13,223	8.9 (8.2)	11.0	40	37	31	25	16	11
38	05/22/06	8:55	1.2	93.5	3.5	276.8	1,762	150,121	157	13,380	8.4 (7.9)	24.5	42	39	33	27	18	12
	05/27/06	8:00	2.4	95.9	6.8	283.6	3,575	153,696	319	13,699	8.8 (8.5)	24.8	48	45	38	32	22	16

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

Week No.	Date	Time	Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
			Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Booster Pump/ System Average (Instanteous) Flowrate	Well Pump Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
39	05/30/06	15:00	0.4	97.3	1.1	284.7	567	154,263	51	13,750	8.6 (9.9)	23.6	51	48	41	35	22	16
	05/31/06	14:45	0.4	97.7	1.2	285.9	637	154,900	57	13,807	8.8 (9.2)	26.5	49	45	39	33	22	17
	06/01/06	9:00	0.2	97.9	1.0	286.9	525	155,425	47	13,854	8.8 (7.6)	43.8	40	37	30	26	16	12
	06/02/06	11:00	0.5	98.4	1.2	288.1	583	156,008	52	13,906	8.1 (7.9)	19.4	36	33	27	21	15	10
40	06/05/06	13:00	0.9	99.3	2.3	290.4	1,367	157,375	122	14,028	9.9 (8.6)	25.3	41	38	32	26	16	11
	06/07/06	7:45	1.3	100.6	2.3	292.7	628	158,003	56	14,084	4.6 (9.2)	28.1	48	45	38	32	21	16
41	06/13/06	7:30	1.6	102.2	4.4	297.1	2,808	160,811	250	14,334	10.6 (9.1)	29.3	42	39	33	26	18	12
	06/14/06	15:30	0.2	102.4	0.5	297.6	278	161,089	25	14,359	9.3 (8.6)	23.2	41	38	32	26	16	11
42	06/21/06	7:40	1.1	103.5	0.6	298.2	296	161,385	26	14,385	8.2 (8.9)	4.5	41	36	31	26	16	12
43	06/28/06	8:00	2.1	105.6	1.2	299.4	705	162,090	63	14,448	9.8 (12.0)	5.6	51	48	41	34	23	17
	06/29/06	9:30	0.1	105.7	0.2	299.6	112	162,202	10	14,458	9.3 (11.5	18.7	41	38	33	26	17	12
44	07/06/06	8:00	0.6	106.3	0.6	300.2	356	162,558	32	14,490	9.9 (8.6)	9.9	41	36	29	23	16	11
45	07/13/06	14:00	3.0	109.3	4.7	304.91	2,513	165,071	224	14,714	8.9 (9.0)	14.0	49	46	39	32	21	16
46	07/20/06	8:00	1.6	110.9	0.7	305.6	402	165,473	36	14,750	9.6 (9.2)	4.2	41	38	32	26	16	12
47	07/27/06	11:30	0.9	111.8	1.6	307.2	912	166,385	81	14,831	9.5 (8.1)	16.9	55	52	44	36	25	19
50	08/16/06	11:05	5.3	117.1	7.1	314.3	3,904	170,289	348	15,179	9.2 (8.5)	12.3	40	36	30	24	16	11
51	08/24/06	7:40	1.6	118.7	2.0	316.3	1,086	171,375	97	15,276	9.1 (8.5)	11.3	41	39	33	27	18	12
52	08/28/06	15:00	1.9	120.6	4.7	321.0	2,500	173,875	223	14,499	8.9 (13.1)	21.9	44	41	34	27	18	12
	08/29/06	9:30	0.4	121.0	1.0	322.0	520	174,395	46	15,545	8.7 (9.4)	21.7	49	46	39	32	21	16
	08/31/06	9:29	1.5	121.5	3.9	325.9	2,034	176,429	181	15,726	8.7 (8.0)	22.6	35	32	26	21	12	8

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

Week No.	Date	Time	Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
			Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Booster Pump/ System Average (Instanteous) Flowrate	Well Pump Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
53	09/05/06	10:45	1.6	123.1	3.5	329.4	2,164	178,593	193	15,919	10.3 (9.6)	22.5	55	53	48	40	30	23
	09/07/06	11:30	0.9	124.0	3.0	332.4	1,927	180,520	172	16,091	10.7 (9.3)	35.7	58	55	47	39	27	20
	09/08/06	12:00	1.3	125.3	1.3	333.7	855	181,375	76	16,167	11.0 (11.9)	11.0	60	58	50	42	30	22
54	09/11/06	11:00	0.7	126.0	1.2	334.9	861	182,236	77	16,244	12.0 (8.2)	20.5	39	36	29	22	14	9
	09/13/06	9:00	1.2	127.2	2.4	337.3	1,557	183,793	139	16,383	10.8 (8.3)	21.6	40	36	30	26	16	11
55	09/19/06	13:00	5.4	132.6	8.6	345.9	3,143	186,936	280	16,663	6.1 (8.9)	9.7	45	42	35	30	20	15
	09/20/06	11:00	0.9	133.5	1.9	347.8	1,227	188,163	109	16,772	10.8 (8.1)	22.7	48	45	38	32	22	16
	09/21/06	11:35	1.1	134.6	2.1	349.9	1,313	189,476	117	16,889	10.4 (8.3)	19.9	49	47	42	37	27	23
	09/22/06	13:30	0.9	135.5	1.8	351.7	1,171	190,647	104	16,993	10.8 (14.5)	21.7	46	43	36	29	18	14
56	09/26/06	14:00	2.0	137.5	2.2	353.9	1,631	192,278	145	17,138	12.4 (8.9)	13.6	55	52	46	39	30	24
57	10/03/06	14:00	2.7	140.2	3.3	357.2	3,727	196,005	332	17,470	18.8 (10.0)	23.0	57	54	45	37	26	19
	10/05/06	10:15	0.9	141.1	0.7	357.9	949	196,954	85	17,555	22.6 (10.1)	17.6	56	55	48	40	28	21
58	10/11/06	10:30	2.0	143.1	1.9	259.8	2,230	199,184	199	17,754	19.6 (10.2)	18.6	55	51	43	36	24	18
59	10/17/06	8:00	2.3	145.4	1.9	361.7	2,723	201,907	243	17,997	23.9 (10.3)	19.7	55	51	44	36	24	18
	10/18/06	10:30	0.8	146.2	0.8	362.5	798	202,705	71	18,068	16.6 (1.6)	16.6	61	60	60	59	56	56
	10/20/06	12:50	3.7	149.9	4.8	367.3	3,623	206,328	323	18,391	12.6 (9.8)	16.3	55	52	45	38	26	19
60	10/23/06	12:00	0.5	150.4	0.4	367.7	541	206,869	48	18,439	22.5 (9.5)	18.0	52	50	45	38	28	22
61	10/31/06	12:50	3.8	154.2	3.2	370.9	4,220	211,089	376	18,815	22.0 (9.9)	18.5	57	55	47	40	28	22
63	11/14/06	12:30	5.0	159.2	4.3	375.2	5,745	216,834	512	19,327	22.3 (10.1)	19.2	64	62	56	49	38	31
	11/15/06	10:30	0.6	159.8	0.3	375.5	456	217,290	41	19,368	25.3 (7.1)	15.2	53	51	43	38	28	23
	11/16/06	8:50	0.5	160.3	0.5	376.0	620	217,910	55	19,423	20.7 (15.5)	20.7	52	50	44	36	26	20

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

Week No.	Date	Time	Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
			Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Booster Pump/ System Average (Instanteous) Flowrate	Well Pump Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
65	11/27/06	12:55	2.3	162.6	1.9	377.9	2,230	220,140	199	19,622	19.6 (10.0)	16.1	53	50	42	36	26	19
	11/28/06	13:05	0.6	163.2	0.4	378.3	646	220,786	58	19,680	26.9 (10.3)	17.9	52	50	43	37	26	20
66	12/07/06	14:00	3.8	167.0	3.2	381.5	4,399	225,185	392	20,072	22.9 (9.9)	19.2	54	51	45	37	26	21
67	12/11/06	9:30	1.8	168.8	1.6	383.1	2,042	227,227	182	20,254	21.3 (9.9)	18.9	52	49	42	36	24	18
	12/12/06	14:00	0.9	169.7	0.9	384.0	1,079	228,306	96	20,350	20.0 (9.8)	20.0	51	49	42	36	24	18
	12/13/06	8:45	0.1	169.8	0.1	384.1	137	228,443	12	20,362	22.8 (9.8)	22.8	57	54	46	40	28	21
68	12/19/06	8:00	2.3	172.1	1.9	386.0	2,576	231,019	230	20,592	22.6 (9.6)	18.7	52	50	44	37	27	20
	12/20/06	14:00	1.0	173.1	0.8	386.8	1,088	232,107	97	20,689	22.7 (10.5)	18.1	55	51	43	36	23	18
71	01/08/07	14:30	1.3	174.4	1.0	387.8	1,473	233,580	131	20,820	24.6 (10.7)	18.9	64	61	55	46	32	26
	01/090/7	14:10	0.5	174.9	0.5	388.3	591	234,171	53	20,873	19.7 (10.2)	19.7	56	53	46	38	26	19
	01/10/07	13:30	0.5	175.4	0.4	388.7	521	234,692	46	20,919	21.7 (11.1)	17.4	55	51	44	36	24	18
72	01/18/07	7:00	2.6	178.0	2.1	390.8	2,970	237,662	265	21,184	23.6 (10.1)	19.0	60	56	50	42	31	24
74	01/31/07	8:00	5.2	183.2	4.1	394.9	6,032	243,694	538	21,722	24.5 (9.9)	19.3	55	53	45	39	26	20
	02/02/07	14:30	1.3	184.5	1.1	396.0	1,516	245,210	135	21,857	23.0 (9.7)	19.4	55	53	45	39	26	20
75	02/05/07	13:30	0.4	184.9	0.3	396.3	480	245,690	43	21,900	26.7 (9.8)	20.0	56	54	47	41	28	22
	02/06/07	8:30	0.2	185.1	0.1	396.4	192	245,882	17	21,917	32.0 (9.6)	16.0	63	62	54	48	37	31
76	02/14/07	13:00	3.9	189.0	3.1	399.5	4,513	250,395	402	22,319	24.3 (9.4)	19.3	53	50	43	36	26	21
	02/15/07	10:00	0.4	189.4	0.4	399.9	506	250,901	45	22,364	21.1 (9.7)	21.1	56	54	47	40	28	22
77	02/22/07	7:00	2.1	191.5	1.6	401.5	2,400	253,301	214	22,578	25.0 (10.8)	19.0	55	52	44	38	28	22
79	03/07/07	8:00	3.6	195.1	3.1	404.6	353	253,654	31	22,909	1.9 (10.1)	1.6	56	54	47	41	28	21
	03/08/07	8:15	0.5	195.6	0.5	405.1	634	254,288	57	22,666	21.1 (10.1)	21.1	56	54	47	41	28	21

EPA Arsenic Demonstration Project at Richmond Elementary School in Susanville, CA – Summary of Daily System Operation

Week No.	Date	Time	Well No. 2 Hour Meter		Booster Pump Hour Meter		Treatment System Flow Readings						Treatment System Pressure Readings					
			Operational Hours	Cumulative Operational Hours	Operational Hours[a]	Cumulative Operational Hours	Volume Treated	Cumulative Volume Treated	Bed Volumes Treated[b]	Cumulative Bed Volumes Treated	Booster Pump/ System Average (Instanteous) Flowrate	Well Pump Average Flowrate	IN	OA	OB	TA	TB	TC
			hrs	hrs	hrs	hrs	gal	gal	BV	BV	gpm	gpm	psi	psi	psi	psi	psi	psi
80	03/14/07	15:30	3.0	198.6	2.8	407.9	3,544	257,832	316	22,982	21.1 (-)	19.7	-	-	-	-	-	-
	03/15/07	8:30	0.4	199.0	0.3	408.2	476	258,308	42	23,024	26.4 (10.4)	19.8	55	53	46	36	28	20
81	03/23/07	12:00	4.1	203.1	3.3	411.5	4,807	263,115	428	23,452	24.3 (9.7)	19.5	56	54	46	38	28	22
82	03/28/07	7:00	1.7	204.8	1.5	413.0	2,056	265,171	183	23,635	22.8 (10.2)	20.2	55	53	46	38	30	22
83	04/04/07	14:00	3.3	208.1	2.8	415.8	3,801	268,972	339	23,974	22.6 (10.1)	19.2	59	57	46	36	26	19
84	04/14/07	11:00	2.8	210.9	2.6	418.4	3,216	272,188	287	24,261	20.6 (11.1)	19.1	59	56	47	36	26	18
85	04/19/07	8:15	1.1	212.0	1.3	419.7	1,418	273,606	126	24,387	18.2 (10.5)	21.5	60	57	49	39	29	21
	04/20/07	11:00	1.0	213.0	0.8	420.5	1,199	274,805	107	24,494	25.0 (10.3)	20.0	56	54	48	38	30	22
86	04/27/07	12:50	3.9	216.9	3.8	424.3	4,816	279,621	429	24,923	21.1 (10.4)	20.6	60	58	50	40	32	26
89	05/14/07	13:00	7.5	224.4	7.0	431.3	9,160	288,781	816	25,739	21.8 (9.7)	20.4	57	55	48	40	32	25
	05/16/07	8:00	0.9	225.3	0.6	431.9	948	289,729	84	25,823	26.3 (11.3)	17.6	57	55	48	40	32	25
90	05/23/07	14:30	3.9	229.2	3.8	435.7	4,707	294,436	420	26,243	20.6 (10.2)	20.1	59	57	49	44	33	25
91	06/01/07	12:50	3.8	233.0	3.3	139.0	4,495	298,931	401	26,644	22.7 (11.1)	19.7	57	55	46	36	26	18
93	06/13/07	8:00	4.5	237.5	2.6	441.6	4,029	302,960	359	27,003	25.8 (10.1)	14.9	55	53	45	35	28	21

(a) booster pump hours estimated by multiplying well pump hours by 2.77 until booster pump hour meter installed on 12/09/05.
(b) 1 bed volume = 1.5 ft^3 = 11.22 gal

APPENDIX B

ANALYTICAL DATA TABLES

Analytical Results from Long-Term Sampling, Susanville, CA

Sampling Date		09/19/05			10/17/05				11/02/05						11/21/05					
Sampling Location / Parameter	Unit	IN	OA	TA	IN	OA	TA	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	0.5	-	-		1.8	-	-	-	-	-	3.7	-	-	-	-	-	4.5
Alkalinity (as $CaCO_3$)	mg/L	88	97	92	88	88	88	88	-	-	-	-	-	-	88	-	92	-	-	88
Fluoride	mg/L	0.2	0.2	<0.1	0.2	0.2	0.2	<0.1	-	-	-	-	-	-	0.2	-	0.1	-	-	0.1
Iodine (ICPMS)	µg/L	-	-	-	20.1	122	263	264	-	-	-	-	-	-	-	-	-	-	-	-
Iodine (AAL)	mg/L	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Iodide	mg/L	-	-	-	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	18.0	18.0	20.0	17.5	17.6	17.9	19.2	-	-	-	-	-	-	16.9	-	17.1	-	-	17.2
Sulfide	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	-	-	-	-	-	-	<0.05	-	<0.05	-	-	<0.05
Orthophosphate	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	-	-	-	-	-	-	-	<10	<10	<10	<10	-	<10	<10	-	<10	-	-	<10
Silica (as SiO_2)	mg/L	13.4	8.7	2.2	13.5	8.5	3.7	0.8	14.2	6.2	5.6	4.4	3.3	2.3	14.5	8.2	6.9	4.5	3.2	2.3
Turbidity	NTU	0.4	0.9	0.2	0.2	0.2	0.4	0.2	-	-	-	-	-	-	0.7	-	<0.1	-	-	0.4
pH	S.U.	8.4	7.8	7.4	8.3	8.1	7.7	7.6	NA[a]	NA[a]	-	NA[a]	-	NA[a]	8.4	8.2	-	7.8	-	7.7
Temperature	°C	16.2	15.9	15.8	14.5	14.0	13.6	13.6	NA[a]	NA[a]	-	NA[a]	-	NA[a]	12.8	12.3	-	12.8	-	12.8
DO	mg/L	1.2	0.5	0.4	3.0	2.6	2.8	2.6	NA[a]	NA[a]	-	NA[a]	-	NA[a]	0.9	0.8	-	0.8	-	0.9
ORP	mV	162	141	135	181	184	191	197	NA[a]	NA[a]	-	NA[a]	-	NA[a]	207	210	-	216	-	218
Total Hardness (as $CaCO_3$)	mg/L	43.4	40.9	40.9	41.1	41.3	40.2	38.7	46.2	48.2	50.7	58.3	-	58.7	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	34.3	32.4	32.4	31.5	31.6	30.8	29.5	36.1	38.5	40.2	46.5	43.1	48.0	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	9.0	8.5	8.5	9.6	9.7	9.4	9.2	10.0	9.8	10.5	11.7	-	10.7	-	-	-	-	-	-
As (total)	µg/L	31.1	2.1	0.2	33.6	6.9	0.2	0.1	32.4	3.2	0.6	<0.1	<0.1	<0.1	30.4	6.3	0.4	<0.1	<0.1	<0.1
As (soluble)	µg/L	31.7	1.6	<0.1	-	-	-	-	32.4	3.3	0.6	-	-	<0.1	-	-	-	-	-	-
As (particulate)	µg/L	<0.1	0.5	<0.1	-	-	-	-	<0.1	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	28.3	0.5	0.4	-	-	-	-	28.5	0.1	0.1	-	-	0.2	-	-	-	-	-	-
As (V)	µg/L	3.4	1.1	<0.1	-	-	-	-	3.9	3.2	0.5	-	-	<0.1	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	41	<25	<25	<25	<25	<25	47	-	<25	-	-	<25
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	<25	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	4.9	0.1	<0.1	4.5	<0.1	<0.1	<0.1	5.2	0.3	0.1	<0.1	<0.1	0.2	5.3	-	<0.1	-	-	0.5
Mn (soluble)	µg/L	5.1	<0.1	<0.1	-	-	-	-	5.0	0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
Al (total)	µg/L	2.7	31.2	22.7	<10	20.6	20.3	17.5	2.7	20.9	34.7	35.3	-	31.6	<10	-	14.2	-	-	29.2
Al (soluble)	µg/L	2.0	27.7	21.8	-	-	-	-	1.9	17.8	23.0	-	-	31.8	-	-	-	-	-	-

(a) Water quality measurements not recorded by operator.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		11/29/05						12/14/05						01/05/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	4.6	-	-	-	-	-	5.4	-	-	-	-	-	5.9
Alkalinity (as $CaCO_3$)	mg/L	-	-	-	-	-	-	89	-	85	-	-	87	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	0.1	-	0.2	-	-	<0.1	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	4.5	-	196	-	-	193	11.3	-	152	-	-	84.6	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	16.0	-	16.0	-	-	17.0	-	-	-	-	-	-
Sulfide	µg/L	-	-	-	-	-	-	<5	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	<0.05	-	<0.05	-	-	<0.05	-	-	-	-	-	-
Total P (as P)	µg/L	-	-	-	-	-	-	<10	-	<10	-	-	<10	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.1	10.9	7.8	5.7	3.9	2.3	NA[b]	11.2	8.8	6.7	4.4	3.1	14.6	9.8	9.1	6.1	4.4	3.2
Turbidity	NTU	-	-	-	-	-	-	1.1	-	0.2	-	-	0.9	-	-	-	-	-	-
pH	S.U.	8.4	7.9	-	7.6	-	7.6	8.5	8.1	7.7	-	-	7.6	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	13.9	14.1	-	14.2	-	13.9	13.9	14.8	14.7	-	-	15.0	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	1.6	1.5	-	2.0	-	2.5	1.5	1.9	2.3	-	-	1.9	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	134	168	-	175	-	178	198	191	194	-	-	199	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	43.3	-	41.3	-	-	43.4	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	35.6	-	33.6	-	-	35.6	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	7.7	-	7.7	-	-	7.8	-	-	-	-	-	-
As (total)	µg/L	31.5	10.7	0.6	0.1	<0.1	0.1	32.8	17.1	0.8	<0.1	<0.1	<0.1	31.1	17.9	0.8	<0.1	<0.1	<0.1
As (soluble)	µg/L	31.4	-	0.4	-	-	0.1	-	-	-	-	-	-	31.8	17.9	0.7	-	-	<0.1
As (particulate)	µg/L	<0.1	-	0.1	-	-	<0.1	-	-	-	-	-	-	<0.1	<0.1	0.1	-	-	<0.1
As (III)	µg/L	8.9	-	0.3	-	-	0.4	-	-	-	-	-	-	10.0	<0.1	<0.1	-	-	<0.1
As (V)	µg/L	22.5	-	0.2	-	-	<0.1	-	-	-	-	-	-	21.8	17.9	0.7	-	-	<0.1
Fe (total)	µg/L	39	-	<25	-	-	<25	26	-	<25	-	-	<25	55	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	<25	-	<25	-	-	<25	-	-	-	-	-	-	<25	<25	<25	-	-	<25
Mn (total)	µg/L	5.7	-	<0.1	-	-	0.1	4.3	-	<0.1	-	-	<0.1	5.3	<0.1	<0.1	<0.1	<0.1	<0.1
Mn (soluble)	µg/L	5.5	-	<0.1	-	-	<0.1	-	-	-	-	-	-	5.3	<0.1	<0.1	-	-	<0.1
Al (total)	µg/L	<10	-	18.0	-	-	27.0	<10	-	13.9	-	-	20.8	<10	25.8	19.1	23.4	25.2	26.0
Al (soluble)	µg/L	<10	-	17.5	-	-	26.1	-	-	-	-	-	-	<10	23.2	17.3	-	-	-

(a) Water quality measurements not recorded by operator (b) Sampling error.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		01/17/06						02/02/06 [b]						02/16/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	6.3	-	-	-	-	-	7.1	-	-	-	-	-	7.8
Alkalinity (as $CaCO_3$)	mg/L	87	-	84	-	-	84	-	-	-	-	-	-	91	-	87	-	-	79
		87	-	84	-	-	84	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	0.1	-	0.2	-	-	0.1	-	-	-	-	-	-	0.2	-	0.3	-	-	0.3
		0.1	-	0.2	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	4.7	-	46.6	-	-	38.9	-	-	-	-	-	-	1.4	-	17.5	-	-	36.1
		9.1	-	46.9	-	-	39.4	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	16	-	16	-	-	16	-	-	-	-	-	-	23	-	22	-	-	23
		16	-	16	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-
Sulfide	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	8.1	-	-	-	-	-
Nitrate (as N)	mg/L	0.4	-	<0.05	-	-	0.1	-	-	-	-	-	-	<0.05	-	<0.05	-	-	<0.05
		0.1	-	0.2	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	-	<10	-	-	<10	-	-	-	-	-	-	20.5	-	<10	-	-	<10
		<10	-	<10	-	-	<10	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.2	10.4	8.3	6.4	4.5	3.0	14.4	12.8	10.6	8.4	6.1	4.0	15.2	12.5	10.3	8.4	6.0	4.3
		14.7	9.8	8.2	6.3	4.6	2.8	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	1.7	-	2	-	-	2.3	-	-	-	-	-	-	0.7	-	0.6	-	-	0.5
		1.6	-	2.3	-	-	2.7	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA[a]	NA[a]	NA[a]	-	-	NA[a]	8.4	8.2	7.9	-	-	7.6	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	NA[a]	NA[a]	NA[a]	-	-	NA[a]	16.0	14.6	15.0	-	-	15.2	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	NA[a]	NA[a]	NA[a]	-	-	NA[a]	0.0	0.0	0.0	-	-	0.0	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	NA[a]	NA[a]	NA[a]	-	-	NA[a]	321	302	316	-	-	320	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Total Hardness (as $CaCO_3$)	mg/L	39.4	-	35.4	-	-	36.2	-	-	-	-	-	-	43.9	-	42.0	-	-	39.3
		39.7	-	35.9	-	-	36.6	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	30.5	-	27.5	-	-	27.9	-	-	-	-	-	-	34.5	-	32.6	-	-	30.4
		30.9	-	27.8	-	-	28.2	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	8.8	-	7.8	-	-	8.3	-	-	-	-	-	-	9.4	-	9.4	-	-	8.9
		8.8	-	8.2	-	-	8.3	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	33.6	23.3	1.8	0.2	0.2	0.2	29.2	29.1	5.5	0.2	0.1	<0.1	30.1	30.4	7.2	<0.1	<0.1	<0.1
		32.5	22.4	1.6	0.2	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	30.8	30.1	6.1	-	-	0.1	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	12.2	1.2	0.5	-	-	0.3	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	18.6	29.0	5.6	-	-	<0.1	-	-	-	-	-	-
Fe (total)	µg/L	88	-	<25	-	-	<25	39	<25	<25	-	-	<25	45	-	<25	-	-	<25
		85	-	<25	-	-	<25	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	<25	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	5.9	-	<0.1	-	-	<0.1	7.7	0.4	0.4	-	-	0.3	6.9	-	<0.1	-	-	<0.1
		5.8	-	<0.1	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	7.5	0.1	0.2	-	-	0.2	-	-	-	-	-	-
Al (total)	µg/L	1.6	-	19.7	-	-	25.6	<10	24.8	20.0	-	-	22.2	<10	-	25.3	-	-	25.8
		1.8	-	18.6	-	-	25.4	-	-	-	-	-	-	-	-	-	-	-	-
Al (soluble)	µg/L	-	-	-	-	-	-	<10	20.2	15.1	-	-	13.9	-	-	-	-	-	-

(a) Water quality measurements not recorded by operator (b) Water quality measurements were taken on 2/3/2006.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		03/02/06[b]						03/15/06						3/29/06[c]					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	8.4	-	-	-	-	-	8.9	-	-	-	-	-	9.6
Alkalinity (as $CaCO_3$)	mg/L	-	-	-	-	-	-	83	-	79	-	-	83	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	0.2	-	0.2	-	-	0.3	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	-	-	-	-	-	-	24.5	-	57.5	-	-	127	-	-	-	-	-	-
Sulfate	mg/L	- -	- -	- -	- -	- -	- -	17.9 -	- -	17.5 -	- -	- -	18.1 -	- -	- -	- -	- -	- -	- -
Sulfide	µg/L	-	-	-	-	-	-	<5	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	<0.05	-	<0.05	-	-	<0.05	-	-	-	-	-	-
Total P (as P)	µg/L	- -	- -	- -	- -	- -	- -	<10 -	- -	<10 -	- -	- -	<10 -	- -	- -	- -	- -	- -	- -
Silica (as SiO_2)	mg/L	15.3	12.9	10.7	8.5	6.6	5.2	13.2	12.0	9.0	9.0	6.7	4.7	15.2	12.4	11.9	11.1	8.8	7.7
Turbidity	NTU	-	-	-	-	-	-	1.5	-	1.2	-	-	1.1	-	-	-	-	-	-
pH	S.U.	8.6	8.4	8.3	-	-	8.0	NA[a]	NA[a]	NA[a]	-	-	NA[a]	8.8	8.3	8.1	-	-	7.7
Temperature	°C	14.8	13.9	13.8	-	-	15.1	NA[a]	NA[a]	NA[a]	-	-	NA[a]	14.3	14.3	14.6	-	-	14.6
DO	mg/L	-	-	-	-	-	-	NA[a]	NA[a]	NA[a]	-	-	NA[a]	0.3	0.4	0.6	-	-	0.3
ORP	mV	329	338	341	-	-	342	NA[a]	NA[a]	NA[a]	-	-	NA[a]	298	287	287	-	-	288
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	33.2	-	31.3	-	-	31.1	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	25.1	-	23.5	-	-	23.4	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	8.1	-	7.8	-	-	7.7	-	-	-	-	-	-
As (total)	µg/L	28.3	29.1	9.7	0.1	<0.1	0.1	25.6	24.5	10.7	<0.1	<0.1	<0.1	32.7	29.5	27.5	3.1	0.5	0.1
As (soluble)	µg/L	28.9	29.2	9.3	-	-	0.1	-	-	-	-	-	-	32.1	29.3	27.7	-	-	0.1
As (particulate)	µg/L	<0.1	<0.1	0.4	-	-	<0.1	-	-	-	-	-	-	0.6	0.2	<0.1	-	-	<0.1
As (III)	µg/L	12.1	0.4	0.4	-	-	0.1	-	-	-	-	-	-	15.0	1.8	1.2	-	-	0.2
As (V)	µg/L	16.7	28.8	8.9	-	-	<0.1	-	-	-	-	-	-	17.1	27.5	26.6	-	-	<0.1
Fe (total)	µg/L	55	<25	<25	<25	<25	<25	<25	-	<25	-	-	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	25	<25	<25	-	-	<25	-	-	-	-	-	-	<25	<25	<25	-	-	<25
Mn (total)	µg/L	6.5	<0.1	<0.1	<0.1	<0.1	<0.1	6.5	-	<0.1	-	-	<0.1	5.5	<0.1	<0.1	<0.1	<0.1	<0.1
Mn (soluble)	µg/L	6.5	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-	5.2	<0.1	<0.1	-	-	<0.1
Al (total)	µg/L	<10	21.3	18.1	18.0	18.8	19.1	<10	-	19.8	-	-	21.9	<10	28.0	27.2	27.1	24.6	22.3
Al (soluble)	µg/L	<10	17.9	16.5	-	-	18.5	-	-	-	-	-	-	<10	29.1	28.5	-	-	23.7

(a) Water quality measurements not recorded by operator (b) Water quality measurements taken on 03/09/06 (c) Water quality measurements taken on 03/30/06.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		04/11/06[b]						04/27/06						05/08/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	10.3	-	-	-	-	-	10.8	-	-	-	-	-	12.1
Alkalinity (as $CaCO_3$)	mg/L	92	-	97	-	-	88	-	-	-	-	-	3	83	-	83	-	-	88
		92	-	97	-	-	92	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	0.2	-	0.3	-	-	0.3	-	-	-	-	-	-	0.2	-	0.2	-	-	0.2
		0.2	-	0.3	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	4.4	-	242	-	-	176
Sulfate	mg/L	18.2	-	18.5	-	-	18.5	-	-	-	-	-	-	15	-	18	-	-	19
		18.5	-	18.4	-	-	18.5	-	-	-	-	-	-	-	-	-	-	-	-
Sulfide	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<5	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	-	<0.05	-	-	<0.05	-	-	-	-	-	-	0.1	-	0.1	-	-	0.1
		<0.05	-	<0.05	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	-	<10	-	-	<10	-	-	-	-	-	-	16.3	-	<10	-	-	<10
		<10	-	<10	-	-	<10	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.4	11.7	11.4	8.8	7.8	5.7	14.8	13.1	12.9	10.1	8.1	6.5	14.0	11.7	10.2	8.9	7.5	6.7
		14.3	11.3	11.3	8.9	7.4	5.7	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.6	-	0.5	-	-	0.7	-	-	-	-	-	-	1.9	-	0.8	-	-	2.2
		0.5	-	0.5	-	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.4	7.9	7.9	-	-	8.0	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	15.1	16.5	15.8	-	-	15.1	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	23.4	31.3	21.4	-	-	17.3	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	348	323	313	-	-	310	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Total Hardness (as $CaCO_3$)	mg/L	45.4	-	46.9	-	-	47.9	-	-	-	-	-	-	50.8	-	48.5	-	-	49.4
		50.0	-	47.2	-	-	53.6	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	37.5	-	39.0	-	-	40.0	-	-	-	-	-	-	39.4	-	38.5	-	-	39.4
		42.3	-	39.4	-	-	45.9	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	7.9	-	7.9	-	-	7.9	-	-	-	-	-	-	11.3	-	10.0	-	-	10.0
		7.7	-	7.8	-	-	7.7	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	31.8	27.5	23.2	0.7	<0.1	<0.1	87.9	28.4	25.4	1.0	<0.1	<0.1	32.7	12.7	15.3	4.3	0.6	<0.1
		30.8	27.5	23.3	0.7	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	75.0	28.6	25.1	-	-	<0.1	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	12.9	<0.1	0.3	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	28.2	0.3	0.2	-	-	0.2	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	46.8	28.3	24.8	-	-	<0.1	-	-	-	-	-	-
Fe (total)	µg/L	<25	-	<25	-	-	<25	<25	<25	<25	-	-	<25	58	-	<25	-	-	<25
		<25	-	<25	-	-	<25	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	<25	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	6.4	-	<0.1	-	-	<0.1	5.6	<0.1	<0.1	-	-	<0.1	4.5	-	<0.1	-	-	0.2
		6.4	-	<0.1	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	5.8	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
Al (total)	µg/L	<10	-	21.8	-	-	21.0	<10	25.3	26.3	-	-	25.4	<10	-	25.0	-	-	34.1
		<10	-	21.8	-	-	20.8	-	-	-	-	-	-	-	-	-	-	-	-
Al (soluble)	µg/L	-	-	-	-	-	-	<10	24.7	26.0	-	-	24.8	-	-	-	-	-	-

(a) Water quality measurements not recorded by operator (b) Water quality measurements taken on 04/08/06.
Yellow highlight indicates that data are outliers and not used for system evaluation.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued).

Sampling Date		06/01/06						06/07/06						06/21/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	13.8	-	-	-	-	-	14.1	-	-	-	-	-	14.4
Alkalinity (as $CaCO_3$)	mg/L	-	-	-	-	-	-	93	-	97	-	-	93	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	0.3	-	-	0.3	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	-	-	-	-	-	-	2.3	-	39.8	-	-	43.0	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	19	-	-	18	-	-	-	-	-	-
Sulfide	µg/L	<5[b]	-	-	-	-	-	<5	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	<0.05	-	-	<0.05	-	-	-	-	-	-
Total P (as P)	µg/L	-	-	-	-	-	-	<10	-	<10	-	-	<10	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	12.8	11.5	10.6	9.8	8.6	6.5	14.1	13.0	13.1	11.3	9.9	8.1	14.2	12.4	11.3	10.4	9.5	6.9
Turbidity	NTU	-	-	-	-	-	-	1.2	-	1.3	-	-	1.4	-	-	-	-	-	-
pH	S.U.	8.3	8.1	7.9	-	-	7.7	NA[a]	NA[a]	NA[a]	-	-	NA[a]	8.4	8.2	8.0	-	-	7.7
Temperature	°C	17.6	17.7	17.9	-	-	18.0	NA[a]	NA[a]	NA[a]	-	-	NA[a]	16.3	16.3	17.0	-	-	18.3
DO	mg/L	6.6	7.3	8.9	-	-	6.1	NA[a]	NA[a]	NA[a]	-	-	NA[a]	1.2	2.3	0.5	-	-	0.5
ORP	mV	273	271	296	-	-	275	NA[a]	NA[a]	NA[a]	-	-	NA[a]	262	263	262	-	-	261
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	43.9	-	45.9	-	-	47.3	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	35.5	-	37.3	-	-	38.4	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	8.4	-	8.5	-	-	9.0	-	-	-	-	-	-
As (total)	µg/L	25.1	24.6	16.3	5.4	0.6	<0.1	30.2	28.1	21.1	6.4	0.6	<0.1	33.2	32.8	19.5	6.2	0.6	<0.1
As (soluble)	µg/L	27.3	23.8	15.0	-	-	<0.1	-	-	-	-	-	-	33.9	31.4	19.6	-	-	<0.1
As (particulate)	µg/L	<0.1	0.7	1.3	-	-	<0.1	-	-	-	-	-	-	<0.1	1.4	<0.1	-	-	<0.1
As (III)	µg/L	8.3	0.2	0.1	-	-	0.1	-	-	-	-	-	-	6.2	0.8	0.2	-	-	0.2
As (V)	µg/L	19.1	23.7	14.9	-	-	<0.1	-	-	-	-	-	-	27.7	30.6	19.4	-	-	<0.1
Fe (total)	µg/L	44	<25	<25	<25	<25	<25	<25	-	<25	-	-	<25	57	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	41	<25	<25	-	-	<25	-	-	-	-	-	-	39	<25	<25	-	-	<25
Mn (total)	µg/L	4.2	<0.1	<0.1	<0.1	<0.1	<0.1	4.7	-	<0.1	-	-	<0.1	5.7	<0.1	<0.1	<0.1	<0.1	<0.1
Mn (soluble)	µg/L	4.4	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-	5.7	<0.1	<0.1	-	-	0.2
Al (total)	µg/L	<10	22.9	19.0	22.4	25.1	27.0	<10	-	18.2	-	-	26.1	<10	21.3	15.1	23.0	24.5	25.1
Al (soluble)	µg/L	<10	21.8	17.2	-	-	26.2	-	-	-	-	-	-	<10	19.8	14.2	-	-	23.4

(a) Water quality measurements not recorded by operator (b) Analyzed outside of hold time.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		07/06/06						07/20/06						08/01/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	14.5	-	-	-	-	-	14.7	-	-	-	-	-	14.9
Alkalinity (as $CaCO_3$)	mg/L	88	-	84	-	-	84	-	-	-	-	-	-	88	-	88	-	-	84
		84	-	84	-	-	84	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	0.3	-	0.2	-	-	0.2	-	-	-	-	-	-	0.2	-	0.2	-	-	0.3
		0.2	-	0.2	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	5.7	-	256	-	-	682		-		-	-		4.3	-	44	-	-	58
		5.4	-	245	-	-	707		-		-	-		-	-	-	-	-	-
Sulfate	mg/L	18	-	18	-	-	21	-	-	-	-	-	-	18	-	18	-	-	17
		19	-	18	-	-	19	-	-	-	-	-	-	-	-	-	-	-	-
Sulfide	µg/L	-	-	-	-	-	-	<5	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	-	<0.05	-	-	<0.05	-	-	-	-	-	-	<0.05	-	<0.05	-	-	<0.05
		0.1	-	<0.05	-	-	<0.05	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	-	<10	-	-	<10	-	-	-	-	-	-	14.0	-	<10	-	-	<10
		<10	-	<10	-	-	<10	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.4	12.0	9.9	9.3	8.2	6.6	13.2	12.3	9.5	8.6	7.9	6.9	15.7	12.2	11.5	9.7	8.2	7.4
		14.4	11.7	10.0	9.3	8.3	6.2	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.5	-	0.6	-	-	0.3	-	-	-	-	-	-	0.6	-	0.4	-	-	0.6
		0.8	-	0.5	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Total Hardness (as $CaCO_3$)	mg/L	36.7	-	36.1	-	-	34.7	-	-	-	-	-	-	46.6	-	45.1	-	-	44.4
		37.3	-	35.9	-	-	34.5	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	27.7	-	27.5	-	-	26.6	-	-	-	-	-	-	36.4	-	35.9	-	-	35.5
		28.0	-	27.2	-	-	26.6	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	8.9	-	8.6	-	-	8.0	-	-	-	-	-	-	10.2	-	9.2	-	-	8.9
		9.3	-	8.7	-	-	7.9	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	32.1	24.6	14.8	5.5	0.8	4.2	32.2	25.9	15.5	4.4	0.5	<0.1	30.8	23.7	14.2	4.1	0.4	0.1
		30.1	23.3	14.0	5.0	0.4	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	32.2	26.5	15.4	-	-	<0.1	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	<0.1	<0.1	0.2	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	12.8	0.6	0.2	-	-	0.2	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	19.4	25.8	15.1	-	-	<0.1	-	-	-	-	-	-
Fe (total)	µg/L	50	-	<25	-	-	<25	<25	<25	<25	-	-	<25	<25	-	<25	-	-	<25
		67	-	<25	-	-	<25	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	<25	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	5.3	-	0.5	-	-	0.6	3.5	<.01	<0.1	-	-	<0.1	4.0	-	<0.1	-	-	0.1
		5.9	-	0.5	-	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	3.5	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
Al (total)	µg/L	<10	-	22.5	-	-	34.4	<10	34.6	27.8	-	-	40.4	<10	-	26.7	-	-	35.8
		<10	-	23.0	-	-	34.7	-	-	-	-	-	-	-	-	-	-	-	-
Al (soluble)	µg/L	-	-	-	-	-	-	<10	35.0	26.2	-	-	38.6	-	-	-	-	-	-

(a) Water quality measurements not recorded by operator.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		08/29/06[b]						09/13/06[c]						09/27/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	15.5	-	-	-	-	-	16.4	-	-	-	-	-	17.2
Alkalinity (as $CaCO_3$)	mg/L	94	-	101	-	-	101	-	-	-	-	-	-	95	-	93	-	-	95
Fluoride	mg/L	0.3	-	0.3	-	-	0.3	-	-	-	-	-	-	<0.1	-	0.2	-	-	0.2
Iodine (ICPMS)	µg/L		-		-	-			-		-	-		0.8	-	16.2	-	-	21.6
Sulfate	mg/L	21	-	21	-	-	22	-	-	-	-	-	-	24	-	19	-	-	20
Sulfide	µg/L	<5	-	-	-	-	-	6.2	-	-	-	-	-	<5	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	-	<0.05	-	-	<0.05	-	-	-	-	-	-	<0.05	-	<0.05	-	-	<0.05
Total P (as P)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<10	-	<10	-	-	<10
Silica (as SiO_2)	mg/L	13.4 14.0	11.4 11.5	10.4 10.8	9.6 9.3	7.8 7.9	6.9 6.2	13.8 -	12.6 -	10.5 -	9.9 -	8.4 -	7.0 -	14.1 -	12.8 -	12.5 -	10.4 -	9.4 -	8.5 -
Turbidity	NTU	0.3	-	0.5	-	-	0.4	-	-	-	-	-	-	0.7	-	0.2	-	-	0.8
pH	S.U.	8.3	8.2	8.0	-	-	7.8	7.9	7.9	8.6	-	-	8.2	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	15.8	15.6	15.6	-	-	15.9	14.7	14.8	14.7	-	-	14.7	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	266	251	252	-	-	253	266	275	277	-	-	263	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	47.2	-	47.9	-	-	46.0
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	37.6	-	38.1	-	-	36.4
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	9.7	-	9.8	-	-	9.6
As (total)	µg/L	29.3	32.9	23.1	7.1	0.7	<0.1	32.0	30.7	26.6	10.4	1.1	0.1	32.4	31.2	32.0	16.0	2.2	0.2
As (soluble)	µg/L	31.2	29.3	21.8	-	-	<0.1	32.0	31.2	26.1	-	-	0.1	-	-	-	-	-	-
As (particulate)	µg/L	<0.1	3.6	1.6	-	-	<0.1	<0.1	<0.1	0.5	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	7.6	1.7	1.2	-	-	<0.1	9.8	1.8	0.5	-	-	0.3	-	-	-	-	-	-
As (V)	µg/L	23.6	27.6	20.6	-	-	<0.1	22.2	29.4	25.6	-	-	<0.1	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	-	-	<25	<25	-	<25	-	-	<25
Fe (soluble)	µg/L	<25	<25	<25	-	-	<25	<25	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	3.6	<0.1	<0.1	<0.1	<0.1	<0.1	4.2	<0.1	<0.1	-	-	<0.1	5.2	-	<0.1	-	-	<0.1
Mn (soluble)	µg/L	3.8	<0.1	<0.1	-	-	<0.1	4.2	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
Al (total)	µg/L	<10	27.9	24.4	28.4	29.8	29.3	<10	27.2	23.3	-	-	28.6	<10	-	24.5	-	-	26.4
Al (soluble)	µg/L	<10	25.2	24.3	-	-	28.8	<10	25.3	23.7	-	-	27.4	-	-	-	-	-	-

(a) Water quality measurements not recorded by operator (b) Samples were collected on 8/29/06 and 8/30/06 (only one set of samples were analyzed with the exception of silica (c) Water quality measurements taken on 09/20/06.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		10/11/06[b]						10/26/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	17.7	-	-	-	-	-	18.6
Alkalinity (as $CaCO_3$)	mg/L	-	-	-	-	-	-	91	-	91	-	-	91
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	-	-	-	-	-	-	4.6	-	36.7	-	-	22.4
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Sulfide	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	13.6	12.1	11.2	9.6	8.5	7.7	13.9	13.2	11.1	11.2	10.0	9.3
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.0	8.0	7.9	-	-	7.5	NA[a]	NA[a]	-	NA[a]	-	NA[a]
Temperature	°C	15.1	14.8	14.8	-	-	15.5	NA[a]	NA[a]	-	NA[a]	-	NA[a]
DO	mg/L	2.2	1.5	1.4	-	-	1.0	NA[a]	NA[a]	-	NA[a]	-	NA[a]
ORP	mV	285	259	258	-	-	257	NA[a]	NA[a]	-	NA[a]	-	NA[a]
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	34.7	32.8	36.9	22.2	3.3	0.2	34.0	30.4	37.2	29.3	7.0	0.6
As (soluble)	µg/L	34.9	31.3	36.5	-	-	0.3	-	-	-	-	-	-
As (particulate)	µg/L	<0.1	1.5	0.4	-	-	35.6	-	-	-	-	-	-
As (III)	µg/L	7.1	0.4	0.5	-	-	0.6	-	-	-	-	-	-
As (V)	µg/L	27.8	30.8	36.0	-	-	<0.1	-	-	-	-	-	-
Fe (total)	µg/L	25	<25	<25	<25	<25	<25	40	-	<25	-	-	<25
Fe (soluble)	µg/L	12	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	5.0	<0.1	<0.1	<0.1	<0.1	<0.1	5.5	-	<0.1	-	-	0.2
Mn (soluble)	µg/L	4.9	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
Al (total)	µg/L	<10	26.1	25.0	20.7	27.3	25.1	<10	-	21.6	-	-	24.9
Al (soluble)	µg/L	<10	23.6	23.7	-	-	24.4	-	-	-	-	-	-

(a) Water quality measurements not recorded by operator (b) Water quality measurements taken on 10/16/06.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		11/15/06[b]						11/29/06						12/13/06					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	19.3	-	-	-	-	-	19.7	-	-	-	-	-	20.3
Alkalinity (as $CaCO_3$)	mg/L	-	-	-	-	-	-	96	-	90	-	-	92	91	-	97	-	-	95
Iodine (ICPMS)	µg/L	-	-	-	-	-	-	4.5	-	61.1	-	-	26.1	0.5	-	30.5	-	-	30.4
Total P (as P)	µg/L	-	-	-	-	-	-	32.4	29.8	28.8	15.5	14.1	14.6	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.1	13.2	13.0	11.6	11.0	9.4	13.2	11.6	10.8	9.7	7.7	8.0	13.6	12.8	12.4	11.3	10.0	9.0
pH	S.U.	8.3	8.4	8.4	-	-	8.2	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	14.6	15.1	15.3	-	-	15.6	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	0.6	0.5	0.8	-	-	0.5	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	261	232	231	-	-	232	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
As (total)	µg/L	31.9	30.5	36.3	35.2	12.4	0.7	33.6	26.6	31.4	28.8	9.7	0.7	31.0	28.0	33.9	35.9	16.8	1.1
As (soluble)	µg/L	32.4	33.8	37.1	-	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	<0.1	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	13.8	2.0	1.2	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	18.6	31.8	35.9	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	43	<25	<25	-	-	<25	47	<25	<25	<25	<25	<25	34	-	<25	-	-	<25
Fe (soluble)	µg/L	<25	<25	<25	-	-	<25	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	5.3	<0.1	<0.1	-	-	<0.1	4.5	0.1	<0.1	<0.1	<0.1	0.1	5.0	-	<0.1	-	-	<0.1
Mn (soluble)	µg/L	5.2	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Al (total)	µg/L	<10	24.6	25.1	-	-	27.7	<10	21.0	20.0	23.6	24.3	23.8	<10	-	18.6	-	-	21.9
Al (soluble)	µg/L	<10	24.3	23.7	-	-	26.2	-	-	-	-	-	-	-	-	-	-	-	-

(a) Water quality measurements not recorded by operator (b) Water quality measurements taken on 11/16/06.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		12/19/06						01/10/07[b]						01/18/07					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	20.6	-	-	-	-	-	20.9	-	-	-	-	-	21.2
Alkalinity (as $CaCO_3$)	mg/L	94	-	92	-	-	92	-	-	-	-	-	-	91	-	93	-	-	90
Iodine (ICPMS)	µg/L	0.6	-	17.9	-	-	44.9	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.0	12.6	11.6	11.1	9.8	8.7	13.8	11.8	11.3	10.4	9.4	8.1	14.3	13.6	12.2	12.1	10.6	9.9
pH	S.U.	8.3	8.3	8.1	-	-	7.9	8.4	8.3	8.3	-	-	8.0	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	12.7	13.8	13.1	-	-	13.8	11.4	11.6	11.6	-	-	12.5	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	0.9	0.6	0.6	-	-	0.7	-	-	-	-	-	-	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	263	260	259	-	-	259	298	270	267	-	-	264	NA[a]	NA[a]	NA[a]	-	-	NA[a]
As (total)	µg/L	31.6	30.2	32.4	39.9	19.9	1.4	32.1	28.9	33.1	32.8	17.1	1.6	33.0	33.9	34.8	40.1	24.5	3.4
As (soluble)	µg/L	-	-	-	-	-	-	32.8	29.6	34.0	-	-	1.6	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	7.4	0.7	0.7	-	-	0.3	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	25.4	28.9	33.3	-	-	1.3	-	-	-	-	-	-
Fe (total)	µg/L	46	<25	<25	<25	<25	<25	50	<25	<25	-	-	<25	136	-	15	-	-	15
Fe (soluble)	µg/L	-	-	-	-	-	-	31	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	5.3	<0.1	<0.1	<0.1	<0.1	<0.1	5.5	<0.1	<0.1	-	-	<0.1	7.3	-	<0.1	-	-	<0.1
Mn (soluble)	µg/L	-	-	-	-	-	-	5.8	0.3	0.3	-	-	0.3	-	-	-	-	-	-
Al (total)	µg/L	<10	-	18.5	-	-	21.2	<10	16.5	17.4	-	-	20.7	3.1	-	24.8	-	-	29.5
Al (soluble)	µg/L	-	-	-	-	-	-	<10	15.7	16.9	-	-	19.6	-	-	-	-	-	-

(a) Water quality measurements not taken by operator (b) Water quality measurements taken on 01/12/07.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		01/31/07[b]						02/15/07						03/07/07					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	21.7	-	-	-	-	-	22.3	-	-	-	-	-	22.6
Alkalinity (as $CaCO_3$)	mg/L	-	-	-	-	-	-	90	-	87	-	-	90	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	13.8	12.9	11.8	11.4	9.9	9.7	14.6	11.3	15.7	15.1	12.1	14.1	13.8	13.1	12.3	11.7	10.7	10.0
pH	S.U.	8.4	8.2	8.2	-	-	8.0	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
Temperature	°C	13.9	14.5	14.7	-	-	15.2	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
DO	mg/L	2.6	1.3	1.2	-	-	1.4	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
ORP	mV	276	296	297	-	-	309	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]
As (total)	µg/L	34.4	31.8	35.8	38.3	26.5	5.2	31.2	25.8	32.4	36.2	29.3	7.4	29.8	26.2	28.8	33.6	30.8	8.9
As (soluble)	µg/L	33.1	30.3	32.7	-	-	5.5	-	-	-	-	-	-	28.8	24.9	27.4	-	-	8.6
As (particulate)	µg/L	1.3	1.5	3.1	-	-	<0.1	-	-	-	-	-	-	1.0	1.3	1.4	-	-	0.3
As (III)	µg/L	13.9	1.2	1.0	-	-	1.0	-	-	-	-	-	-	8.6	0.6	0.3	-	-	0.2
As (V)	µg/L	19.2	29.1	31.7	-	-	4.5	-	-	-	-	-	-	20.2	24.3	27.1	-	-	8.4
Fe (total)	µg/L	30	<25	<25	-	-	<25	28.7	-	<25	-	-	<25	28	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	-	-	<25	-	-	-	-	-	-	<25	<25	<25	-	-	<25
Mn (total)	µg/L	6.1	0.1	<0.1	-	-	<0.1	5.9	-	<0.1	-	-	<0.1	6.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mn (soluble)	µg/L	6.0	<0.1	<0.1	-	-	0.2	-	-	-	-	-	-	5.9	<0.1	<0.1	-	-	<0.1
Al (total)	µg/L	<10	36.2	34.3	-	-	40.9	<10	-	25.9	-	-	31.1	<10	28.7	29.0	34.7	37.5	37.3
Al (soluble)	µg/L	<10	35.4	31.7	-	-	38.6	-	-	-	-	-	-	<10	29.3	29.0	-	-	36.5

(a) Water quality measurements not taken by operator. (b) Water quality measurements taken on 02/06/07.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		03/15/07[b]						03/28/07						04/19/07					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	23.0	-	-	-	-	-	23.8	-	-	-	-	-	24.7
Alkalinity (as $CaCO_3$)	mg/L	121	-	118	-	-	18	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	12.4	15.1	11.6	<10	<10	<10	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.4	13.5	13.0	10.7	1.4	0.5	13.9	12.8	11.7	11.0	1.8	0.4	-	-	-	-	-	-
pH	S.U.	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-
Temperature	°C	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-
DO	mg/L	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-
ORP	mV	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-	NA[a]	NA[a]	NA[a]	NA[a]	-	-
As (total)	µg/L	32.7	28.6	32.5	15.0	<0.1	<0.1	32.9	28.5	34.0	23.5	<0.1	<0.1	35.0	31.2	33.2	30.8	0.5	0.3
As (soluble)	µg/L	-	-	-	-	-	-	32.0	27.2	32.7	-	-	<0.1	34.0	30.2	31.7	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	0.9	1.3	1.3	-	-	<0.1	1.0	1.1	1.5	-	-	-
As (III)	µg/L	-	-	-	-	-	-	8.9	<0.1	<0.1	-	-	<0.1	12.8	1.9	0.8	-	-	-
As (V)	µg/L	-	-	-	-	-	-	23.1	27.2	32.7	-	-	<0.1	21.3	28.3	31.0	-	-	-
Fe (total)	µg/L	25	-	<25	-	-	<25	<25	<25	<25	-	-	<25	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	<25	<25	<25	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	6.1	-	<0.1	-	-	0.4	4.2	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	4.0	<0.1	<0.1	-	-	<0.1	-	-	-	-	-	-
Al (total)	µg/L	<10	-	29.5	-	-	<10	<10	27.5	26.4	-	-	<10	-	-	-	-	-	-
Al (soluble)	µg/L	-	-	-	-	-	-	<10	24.7	24.2	-	-	<10	-	-	-	-	-	-

(a) Water quality measurements not taken by operator (b) Media changeout occurred on March 14, 2007 and TC column was moved to lead position and named TA.

Analytical Results from Long-Term Sampling, Susanville, CA (Continued)

Sampling Date		05/16/07						06/13/07					
Sampling Location / Parameter	Unit	IN	OA	OB	TA	TB	TC	IN	OA	OB	TA	TB	TC
Bed Volume	BV	-	-	-	-	-	26.2	-	-	-	-	-	27.3
pH	S.U.	NA[a]	NA[a]	NA[a]	NA[a]	-	-	8.1	8.2	8.2	-	-	7.7
Temperature	°C	NA[a]	NA[a]	NA[a]	NA[a]	-	-	16.5	17.1	16.4	-	-	16.9
DO	mg/L	NA[a]	NA[a]	NA[a]	NA[a]	-	-	1.2	1.2	1.0	-	-	1.4
ORP	mV	NA[a]	NA[a]	NA[a]	NA[a]	-	-	222	209	203	-	-	195
As (total)	µg/L	35.4	28.3	33.4	30.9	<0.1	<0.1	33.2	33.6	31.3	30.9	1.0	<0.1
As (soluble)	µg/L	34.5	26.5	32.0	-	-	-	31.8	32.6	29.3	-	-	-
As (particulate)	µg/L	0.9	1.8	1.4	-	-	-	1.4	1.0	2.0	-	-	-
As (III)	µg/L	11.3	1.1	0.2	-	-	-	10.1	2.7	<0.1	-	-	-
As (V)	µg/L	23.2	25.4	31.9	-	-	-	21.7	29.9	29.3	-	-	-

(a) Water quality measurements not taken by operator.

APPENDIX C

ARSENIC CAPACITY CALCULATIONS

Arsenic Mass Removed by Oxidation Column A

Bed Volumes Treated between Sampling Points	Concentration (µg/L)			µg/L × BV[a]	Mass (µg)
	Influent	OA	Difference		
0	32.0	0.5	31.5	-	-
500	31.1	2.1	29.0	15,125	642,324
1,300	33.6	6.9	26.7	36,205	1,537,543
1,900	32.4	3.2	29.2	53,105	2,255,247
800	30.4	6.3	24.1	21,320	905,411
100	31.5	10.7	20.8	2,245	95,340
800	32.8	17.1	15.7	14,600	620,028
500	31.1	17.9	13.2	7,225	306,829
400	33.6	23.3	10.3	4,700	199,598
800	29.2	29.1	0.1	4,160	176,666
700	30.1	30.4	0.0	35	1,486
Total Arsenic Mass Removed (µg)				6,740,472	
Mass of Media (as is) in Oxidation Column A (mg)				34,700,400	
Media Loading (µg of As/mg of dry media)				**0.20**	

(a) 1 BV = 1.5 ft^3 = 11.22 gal
Dry media in each column = 32,965,380 mg based on a bulk density of 51 lb/ft^3 and 5% moisture content.
OA = after Oxidation Column A

Arsenic Mass Removed by Oxidation Column B

Bed Volumes Treated between Sampling Points	Concentration (µg/L)			µg/L × BV[(a)]	Mass (µg)
	OA	OB	Difference		
0	3.2	0.6	2.6	-	-
800	6.3	0.4	5.9	3,400	144,390
100	10.7	0.6	10.1	800	33,974
800	17.1	0.8	16.3	10,560	448,459
500	17.9	0.8	17.1	8,350	354,605
400	23.3	1.8	21.5	7,720	327,851
800	29.1	5.5	23.6	18,040	766,117
700	30.4	7.2	23.2	16,380	695,621
600	29.1	9.7	19.4	12,780	542,737
500	24.5	10.7	13.8	8,300	352,482
700	29.5	27.5	2.0	5,530	234,846
700	27.5	23.2	4.3	2,205	93,641
3,500	24.6	16.3	8.3	22,050	936,413
300	28.1	21.1	7.0	2,295	97,463
300	32.8	19.5	13.3	3,045	129,314
100	24.6	14.8	9.8	1,155	49,050
200	25.9	15.5	10.4	2,020	85,785
200	23.7	14.2	9.5	1,990	84,511
600	32.9	23.1	9.8	5,790	245,888
900	30.7	26.6	4.1	6,255	265,635
800	31.2	32.0	0.0	1,640	69,647
Total Arsenic Mass Removed (µg)				5,958,431	
Mass of Media (as is) in Oxidation Column B (mg)				34,700,400	
Media Loading (µg of As/mg of dry media)				**0.18**	

(a) 1 BV = 1.5 ft^3 = 11.22 gal

Dry media in each column = 32,965,380 mg based on a bulk density of 51 lb/ft^3 and 5% moisture content.

OA = after Oxidation Column A

OB = after Oxidation Column B

Arsenic Mass Removed by Adsorption Column A

Bed Volumes Treated between Sampling Points	Concentration (µg/L)			µg/L × BV[(a)]	Mass (µg)
	OB	TA	Difference		
0	0.6	0.1	0.6	-	-
800	0.4	0.1	0.4	360	15,288
100	0.6	0.1	0.5	43	1,805
800	0.8	0.1	0.8	500	21,234
500	0.8	0.1	0.8	375	15,925
400	1.8	0.2	1.6	470	19,960
800	5.5	0.2	5.3	2,760	117,211
700	7.2	0.1	7.2	4,358	185,053
600	9.7	0.1	9.6	5,025	213,400
500	10.7	0.1	10.7	5,063	214,993
700	27.5	3.1	24.4	12,268	520,973
700	23.2	0.7	22.5	16,415	697,107
3,500	16.3	5.4	10.9	58,450	2,482,237
300	21.1	6.4	14.7	3,840	163,076
300	19.5	6.2	13.3	4,200	178,364
100	14.8	5.5	9.3	1,130	47,989
200	15.5	4.4	11.1	2,040	86,634
200	14.2	4.1	10.1	2,120	90,032
600	23.1	7.1	16.0	7,830	332,522
900	26.6	10.4	16.2	14,490	615,357
800	32.0	16.0	16.0	12,880	546,984
500	36.9	22.2	14.7	7,675	325,940
900	37.2	29.3	7.9	10,170	431,897
700	36.3	35.2	1.1	3,150	133,773
400	31.4	28.8	2.6	740	31,426
600	33.9	35.9	0.0	780	33,125
Total Arsenic Mass Removed (µg)				7,522,304	
Mass of Media (as is) in Adsorption Column A (mg)				34,700,400	
Media Loading (µg of As/mg of dry media)				**0.23**	

(a) 1 BV = 1.5 ft^3 = 11.22 gal

Dry media in each column = 32,965,380 mg based on a bulk density of 51 lb/ft^3 and 5% moisture content.

OB = after Oxidation Column B

TA = after Adsorption Column A

Arsenic Mass Removed by Adsorption Column B

Bed Volumes Treated between Sampling Points	Concentration (µg/L)			µg/L × BV[(a)]	Mass (µg)
	TA	TB	Difference		
0	0.2	0.2	0.0	-	-
800	0.2	0.1	0.1	40	1,699
700	0.1	0.1	0.0	35	1,486
600	0.1	0.1	0.1	15	637
500	0.1	0.1	0.0	13	531
700	3.1	0.5	2.6	910	38,646
700	0.7	0.1	0.7	1,138	48,307
3,500	5.4	0.6	4.8	9,538	405,036
300	6.4	0.6	5.8	1,590	67,524
300	6.2	0.6	5.6	1,710	72,620
100	5.5	0.8	4.7	515	21,871
200	4.4	0.5	3.9	860	36,522
200	4.1	0.4	3.7	760	32,275
600	7.1	0.7	6.4	3,030	128,677
900	10.4	1.1	9.3	7,065	300,034
800	16.0	2.2	13.8	9,240	392,402
500	22.2	3.3	18.9	8,175	347,173
900	29.3	7.0	22.3	18,540	787,351
700	35.2	12.4	22.8	15,785	670,353
400	28.8	9.7	19.1	8,380	355,879
600	35.9	16.8	19.1	11,460	486,680
300	39.9	19.9	20.0	5,865	249,073
300	32.8	17.1	15.7	5,355	227,415
300	40.1	24.5	15.6	4,695	199,386
500	38.3	26.5	11.8	6,850	290,904
600	36.2	29.3	6.9	5,610	238,244
300	33.6	30.8	2.8	1,455	61,791
Total Arsenic Mass Removed (µg)				5,462,514	
Mass of Media (as is) in Adsorption Column B (mg)				34,700,400	
Media Loading (µg of As/mg of dry media)				**0.17**	

(a) 1 BV = 1.5 ft^3 = 11.22 gal
Dry media in each column = 32,965,380 mg based on a bulk density of 51 lb/ft^3 and 5% moisture content.
TA = after Adsorption Column A
TB = after Adsorption Column B

Arsenic Mass Removed by Adsorption Column C

Bed Volumes Treated between Sampling Points	Concentration (µg/L)			µg/L × BV[(a)]	Mass (µg)
	TB	TC	Difference		
0	0.1	0.1	0.0	-	-
700	0.5	0.1	0.4	140	5,945
700	0.1	0.1	0.0	140	5,945
3,500	0.6	0.1	0.6	963	40,875
300	0.6	0.1	0.6	165	7,007
300	0.6	0.1	0.6	165	7,007
100	0.8	0.1	0.8	65	2,760
200	0.5	0.1	0.5	120	5,096
200	0.4	0.1	0.3	75	3,185
600	0.7	0.1	0.7	285	12,103
900	1.1	0.1	1.0	743	31,532
800	2.2	0.2	2.0	1,200	50,961
500	3.3	0.2	3.1	1,275	54,146
900	7.0	0.6	6.4	4,275	181,549
700	12.4	0.7	11.7	6,335	269,033
400	9.7	0.7	9.0	4,140	175,816
600	16.8	1.1	15.7	7,410	314,686
300	19.9	1.4	18.5	5,130	217,859
300	17.1	1.6	15.5	5,100	216,585
300	24.5	3.4	21.1	5,490	233,148
500	26.5	5.2	21.3	10,600	450,158
600	29.3	7.4	21.9	12,960	550,381
300	30.8	8.9	21.9	6,570	279,013
400	32.5	15.0	17.5	7,880	334,645
800	34.0	23.5	10.5	11,200	475,638
900	33.2	30.8	2.4	5,805	246,525
1,500	33.4	30.9	2.5	3,675	156,069
1,100	31.3	30.9	0.4	1,595	67,736
Total Arsenic Mass Removed (µg)				4,395,407	
Mass of Media (as is) in Adsorption Column C (mg)				34,700,400	
Media Loading (µg of As/mg of dry media)				**0.13**	

(a) 1 BV = 1.5 ft^3 = 11.22 gal

Dry media in each column = 32,965,380 mg based on a bulk density of 51 lb/ft^3 and 5% moisture content.

TB = after Adsorption Column B

TC = after Adsorption Column C